THE EIGHTH INTERNATIONAL SYMPOSIUM ON ENVIRONMENTAL CONCERNS IN RIGHTS-OF-WAY MANAGEMENT

The Eighth International Symposium on Environmental Concerns in Rights-of-Way Management

12–16 September 2004
Saratoga Springs, New York, USA

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Preface

The Eighth International Symposium on Environmental Concerns in Rights-of-Way Management, ROW8, was held September 12–16, 2004 at the Prime Hotel and Conference Center in Saratoga Springs, New York. ROW8 follows a series of symposia begun at Mississippi State University, Mississippi in 1976. Since then, it has been held in six other cities in Canada and the United States. The symposia are organized by a steering committee composed of representatives from industries, agencies, and universities concerned with research and management of electric, pipeline, railroad, and highway rights-of-way.

The purpose of this symposium was to achieve a better understanding of the current and emerging environmental issues related to rights-of-way management by sharing environmental research and practical experience throughout the world. ROW8 attracted 349 participants from 15 countries.

ROW8 was opened by the Sons and Daughters of Liberty Ancient Fifes and Drums Corps, followed by a walk through the rich history of Saratoga Springs by Sean Kelleher of the Center for Heritage Education and Tourism.

The keynote speaker was Peter A.A. Berle, host of "The Environment Show," a public radio and ABC Radio Network program. His many other credits include his work as an environmental lawyer, state legislator, president of the National Audubon Society and involvement in almost every environmental issue that has engaged the nation over the past three decades. Mr. Berle's address focused us on a simple concept, "There are certain basic human values that prevail. Our task in solving problems is to come back to those and achieve success." Following Mr. Berle's address, a panel discussion was held on "When the Lights Go Out: Environmental Choices and Consequences." This discussion focused on the 2003 blackout that left approximately 50 million people without power in Midwestern and Northeastern United States and Ontario, Canada.

During the course of three days, eight concurrent sessions were held on topics such as vegetation management, cultural planning, endangered and threatened species, marine and aquatic environments, pipelines and pipeline management, avian power line interactions, wildlife, invasive species, technology, and siting and routing. A total of 128 papers were presented. Eighty-two peer-reviewed papers appear in this book. The appendix contains a bibliography of presentations not incorporated into the chapters as individual papers.

At this time, the Ninth International Symposium on Environmental Concerns in Rights-of-Way Management has not found a home. Please visit the symposia Web site at www.rights-of-way-env.com for updates.

Acknowledgements

ROW8 would not have been possible without the hard work and dedication of many individuals. First and foremost, we would like to thank the national and local steering committees for their commitment and enthusiasm. Without all of their planning, none of this would be possible. National steering committee members are: Larry Abrahamson (co-chair), Dale Arner, Mike Boyle, Allen Crabtree, Jean Doucet, Jim Evans, John Goodrich-Mahoney, Kevin McLoughlin (co-chair), Dean Mutrie, Chris Nowak, Peter Prier, Richard Skarie, Tom Sullivan, and Gus Tillman. Along with the co-chairs, the local steering committee members are: Craig Allen, Ben Ballard, Jen Ballard, Tami Evans, Ken Finch, Ed Neuhauser, David Frazier, Jim Kooser, Dave Morrell, and Maureen Wakefield.

We would like to recognize the authors of the papers and posters for their efforts and the quality of their contributions, as well as the individuals who served as technical reviewers of the papers. Also, without the determination of Resource Strategies, Inc. this book would never have come to fruition.

We acknowledge the major sponsors: Niagara Mohawk: A National Grid Company, New York Power Authority, Electric Power Research Institute, and SUNY College of Environmental Science and Forestry; the co-sponsors: Avian Power Line Interaction Committee, Ecology and Environment, Inc., Environmental Energy Alliance of New York, Hydro One, Lewis Tree Service, Inc., New York Search/New York Gas Group, Stantec, TRC/Essex Environmental, and URS Corp; and the contributors and supporters: Environmental Consulting, Inc., Hydro-Quebec, and Asplundh.

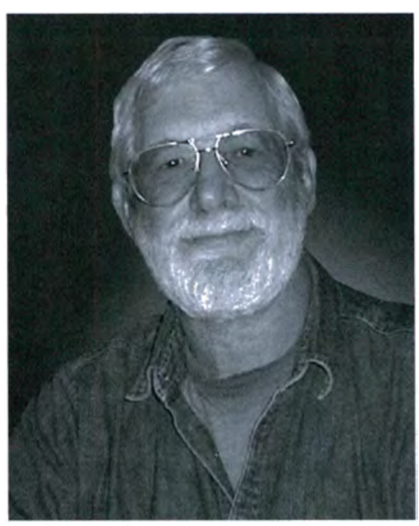
In Memoriam

This book of proceedings is dedicated to Dr. Robert E. "Gus" Tillman, a fine gentleman and great friend to the Rights-of-Way Symposia. Sadly, Dr. Tillman was unable to attend ROW8, and passed away May 31, 2005 after a year-long battle with cancer.

Gus Tillman was raised in Hammondsport in upstate New York. He received a Master's degree from Albany Teachers College, and earned a Ph.D. in Environmental Education and Wildlife Management from Cornell University. Throughout his long and successful career, Gus worked for several organizations as a champion of the environment and for humanity. Through the United Nations Center for Human Settlement and the World Bank, he was able to assist many societies in bettering their ecosystems and environments.

Gus became involved in the very first ROW symposium, held in Mississippi in 1975, as a member of the steering committee. Not only did he continue to serve the steering committees of all eight symposia, he was an editor for two of the proceedings, and co-chair for the San Diego, California ROW3 symposium. Although he was unable to attend ROW8, Gus assisted in the technical review of several of the papers presented in this book. As a dedicated steering committee member, Gus will be missed; as a charismatic and dynamic character, he will never be replaced.

A former employer said it best, "Few other people command the degree of respect, admiration and love that you do. We respect you for your intelligence and wisdom, and for your ability to use them effectively. We admire you for your dedication to principles, and for your understanding of the human condition. We love you because you are able to receive the love of others and return it to them as a professional and with personal joy."



Dr. Robert E. "Gus" Tillman
1937–2005

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Symposium Plenary Session

Plenary Session Opening Remarks and Presentations

THE FOLLOWING IS AN EDITED TRANSCRIPT OF THE PLENARY SESSION OPENING REMARKS AND PRESENTATIONS

[Opening Ceremony by Sons and Daughters of Liberty Ancient Fifes & Drums Corps and Sean Kelleher of the Center for Heritage Education and Tourism.]

WELCOME BY CO-HOST LARRY ABRAHAMSON

Larry Abrahamson

Welcome! We have enjoyed a wonderful opening ceremony by Sean Kelleher and the drum and fifes corps. Thank you, Sean for a job well done.

I want to personally welcome you to the Eighth International Symposium on Environmental Concerns in Rights-of-Way Management. I'm Larry Abrahamson, from the State University of New York College of Environmental Science and Forestry. I'm co-host along with Kevin McLoughlin, who until his recent retirement, was with the New York Power Authority. Kevin and I hope that you find this symposium to be an excellent meeting and well worth your time.

What will make this meeting an excellent meeting is you, the participant. We have 349 people registered for this event. We haven't beaten the attendance record set at the Calgary Symposium, but we're doing very well. We have 15 countries represented: Australia, Burundi, Canada, Costa Rica, Ecuador, France, Gabon, Germany, Japan, South Africa, Spain, Sweden, Thailand, the United Kingdom, and the United States.

There is an important tradition associated with the ROW symposia. The national steering committee organizes and hosts them, but it's the sponsors that make them run. The symposia are staged about every four years. The last one, ROW7, was held in Calgary in 2000. We were very fortunate to have ample interest and support early on for ROW8.

Before I credit all of our sponsors, I want to put in a plug for ROW9. We had intended to announce the date and location for ROW9 at this symposium; unfortunately, the interested parties had to back out. Obviously we don't want to see the ROW symposia die. Because of the interest that we've had in ROW7 and ROW8, we hope that won't happen. Perhaps someone here today will have an interest in hosting ROW9.

Now, I would like to talk about our sponsors because, obviously, without them, we couldn't have done this. I want to mention them here so that you can thank them personally. We certainly appreciate them. Sponsors are the driving force behind these meetings; they help everything run efficiently, and they help keep the registration fee down.

Our major sponsors provided the majority of the funds, and some of them also provided a great deal of manpower. We would not be here today if it weren't for Niagara Mohawk: A National Grid Company. They got this symposium started by contributing the money and manpower to begin moving forward. Next, the New York Power Authority came along as a major co-sponsor. Another major sponsor is the Electric Power Research Institute (EPRI), who will be preparing the proceedings for ROW8. The proceedings are very expensive, and we are very appreciative of that commitment. John Goodrich-Mahoney from EPRI will be speaking later regarding what is involved with the proceedings. Finally, SUNY-ESF, the State University of New York College of Environmental Science and Forestry, came in to supply most of the manpower. ESF is providing the infrastructure for organizing and presiding over this symposium. These are the major sponsors who put up most of the funds and time to administer this symposium.

ROW8 was also very lucky to have a number of co-sponsors, contributors, and supporters. These companies served on the local steering committee, in addition to providing funds to cover our lunches, field trips, and other expenses. They are: the Avian Power Line Interaction Committee (APLIC); Hydro One; TRC/Essex Environment; Ecology & Environment, Inc.; Environmental Energy Alliance of New York; New York Gas Group; URS Corp; Lewis Tree Service, Inc.; Stantec; ECI; Hydro-Quebec; and Asplundh. Please be sure to thank these people.

In addition to the sponsor contributions, your registration fees assist in providing the resources to present and run this symposium. There are 128 presentations being given this week. Of course, without these contributions, there wouldn't be a ROW8.

If you look in your abstracts book, you will notice there are 14 posters being presented. In addition, there are 19 exhibitor booths set up in the dining area. Exhibitors are new for the ROW symposia. This is the

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first year that exhibitors have been invited, and we encourage you to visit the booths, talk to the representatives, and support them. We hope exhibitors will be part of future symposia. They provide a service to the attendees and help defray the costs of running the symposium. After today, the coffee breaks will held be near the posters and exhibitors to help you view the posters and visit the exhibitors.

I would like also to notify you that a number Continuing Education (CE) credits are available for this symposium. There are CE credits for Society of American Foresters, arborists, horticulturists, and others. We also have pesticide applicator certification for a number of states, including New York. Please visit the registration desk to learn more.

Also new this year, are the day-long field trips that have been incorporated into the meeting. There are four separate, all day field trips. Three are technical: 1. the electric power line rights-of-way field trip, 2. the reconstruction and restoration of highway and pipelines field trip, and 3. the wildlife field. The fourth is a non-technical trip to the Adirondacks.

After the plenary session this morning, the rest of the meeting will be held with concurrent sessions. There are a total of eight concurrent sessions: one this afternoon, two on Wednesday, and one Thursday morning. During each of these concurrent sessions, three different topic sessions will run simultaneously, with the exception of Wednesday morning when there will be four concurrent sessions. Each of these topic sessions will be held in a separate room, with anywhere from four to six papers being given in each. We encourage attendees to move among the rooms in order to hear papers in different sessions.

Now, I'd like to introduce John Goodrich-Mahoney. John, will you come up and tell us about the proceedings for this symposium?

John Goodrich-Mahoney

Thank you, Larry, and welcome to everyone. Once again, EPRI will be supporting publication of the proceedings for this symposium. And, I'm very pleased that we are able to do this. We will be publishing the proceedings through Elsevier Science as we did last time, and EPRI will distribute the proceedings to you as part of the registration fee.

There are a few copies of the proceedings from the previous symposium, which are available to educational organizations and for personal use. If you contact me at some point during the symposium, I can arrange to have copies shipped to you or to your library.

Once again, the proceedings will be a peer-reviewed publication. Your papers will be reviewed, and you will be contacted by our reviewers to resolve any concerns before publishing your paper. We expect to have an excellent collection of papers and hope to be able to have the proceedings completed near the end of 2005.

I want to confirm that EPRI will be here for ROW9. We plan to help support the proceedings for ROW9, so, if we can get another major sponsor or two, we'll be on our way. Enjoy the symposium! Thank you very much, Larry.

LARRY ABRAHAMSON INTRODUCES KEVIN MCLOUGHLIN

Larry Abrahamson

Thank you, John. Remember if you would like previous editions of the proceedings, please contact John or for copies of the ROW5, Montreal meeting, contact Jean Doucet.

And with that, I'll introduce Kevin McLoughlin. Kevin is going to preside over the rest of the morning session.

KEVIN MCLOUGHLIN INTRODUCES SCOTT LEUTHAUSER

Kevin McLoughlin

Thank you, Larry. As Larry mentioned earlier, I retired last month from the New York Power Authority, so I look at this meeting as one big retirement party. Let's enjoy ourselves.

Also as Larry mentioned, we are pleased that the Power Authority was able to step forward and match Niagara Mohawk's sponsorship. I'd like to thank Ed Huber for giving us the opportunity to support this symposium. This contribution was one of Ed's first big decisions.

The Power Authority had only been created in June of 2000 and that year Ed was named as the new director. I called Ed from the ROW7 symposium in Calgary to request a matching grant for $35,000. He approved it, so I was able to announce at Calgary New York Power Authority's support for ROW8, which put us over the top.

Today I'm here to introduce a couple of very important people. There is a slight change in the program; Clem Nadeau, who is Senior Vice President of Operations for National Grid, was unable to attend. We have, in his place, Scott Leuthauser, Vice President of Distribution Planning and Engineering. Mr. Leuthauser is responsible for the planning and asset management of National Grid's electric distribution and natural gas delivery facilities. This includes the engineering, planning, and capital resource allocation prioritization. He is a licensed engineer in New York State with a master's certificate in power systems management. He holds both an M.B.A. and a B.S. degree in mechanical engineering. Scott, I welcome you to Saratoga.

Scott Leuthauser

Thank you very much. Clem wanted me to express his apologizes that he could not be here today, but I am pleased to have the opportunity to attend in his place. I had a nice drive down from Speculator, an hour and a half north of here, and I was able to view first hand the beauty of the Adirondacks.

On behalf of National Grid, I'd like to welcome everyone to the Saratoga Springs Rights-of-Way Symposium. I hope you enjoy the historical sites around the area and enjoy your stay. National Grid is pleased to be a major sponsor of the Eighth ROW Symposium.

This venue brings together experts—like you—to share ideas, new procedures, and emerging technologies. It will help us meet the challenges our companies face every day.

As everyone well knows, on August 14, 2003, large portions of the Midwest and Northeast US and Ontario, Canada experienced an electric blackout that affected nearly 50 million people. We have all learned something from that outage. One of those lessons is the importance of good rights-of-way management.

In 1897, the White-Crosby Company presented a paper to the National Electric Light Association in Niagara Falls. This company engineered and constructed a large-scale effort to generate and transmit bulk power. One of the key quotes of that presentation was, "One short interruption last winter was due to the dead limb of a tree blowing across the wires, illustrating the fact that all trees should be cut down for some considerable distance on both sides of any high voltage line."

Thankfully, today we don't have to cut down all the trees. We can use an ecologically-centered approach to right-of-way management, minimizing and avoiding adverse impacts to adjacent lands, water resources, right-of-way vegetation, and wildlife.

Turning to Niagara Mohawk history, which we just heard a little bit about from the town historian, nature itself sculpted many of the early rights-of-way for our predecessor companies. Such was the case for Niagara Mohawk, one of the first companies to transmit power for any distance. The obvious great Niagara Falls, serving as an immense power source, has a lesser-known wonder that made it successful, and it's called the Great Corridor of Waterways across New York. The Hudson River and the Mohawk River served as national corridors for the transmission of electricity, and still do today. The Mohawk River is the only water route through the Appalachian Mountains. It provided a transportation path for early settlers, flowing water to for waterwheels and power turbines, and the genesis of commerce to fund the corridor of upstate New York cities. With the construction of the Erie Canal, this same corridor later became a fully-connected waterway. As technology developed, the New York State Thruway was formed. Of course, anybody who drives along the thruway can follow right along the cross-state transmission lines—the backbone of the New York transmission system—that are primarily owned by Niagara Mohawk and the New York Power Authority.

In the early days, the miller, lumberman, spinner and other users of water power had to come to the source of the power. In the Great Corridor, a series of discoveries and events changed all that: Joseph Henry's first electric motor in the 1820s and 1830s, the war of the currents between AC and DC technical rivalries, Nikola Tesla and Thomas Edison in the 1890s, and the work in Schenectady by Charles Steinmetz, advancing AC power transmission at the turn of the 20th Century. The Corridor's entrepreneurial population helped transform our ideas of energy.

Some of you will be taking field trips tomorrow. Whether you take the integrated vegetation management, wildlife, or construction/restoration tour, you will witness firsthand the results of several years of rights-of-way research, restoration and construction projects.

The focus of this symposium is to share environmental research and practical experience so that we are all better rights-of-way managers, not only for our businesses, but for our environment. I encourage you to sit back and enjoy. Today is the beginning of much more.

I'm going to pass around a book entitled "Niagara Mohawk, an Uncommon History." This book is a history of Niagara Mohawk written by Bob Dischner. Tomorrow some of you will be having lunch with Bob, one of our former head trainers and also our in-house historian. Everybody can think of a few questions to see if you can stump Bob tomorrow.

Thank you very much.

KEVIN MCLOUGHLIN INTRODUCES EUGENE ZELTMANN

Kevin McLoughlin

Thank you very much, Scott. My next job is to introduce Eugene Zeltmann, President and CEO of the New York Power Authority. I'd like to give you a little background on this gentleman, because he came to the Power Authority with the right background, the right experience, at the right time, with the right stuff.

Gene came to the Public Service Commission (PSC) as a Fellow in 1971 and worked with the PSC at a very critical time in the development of environmental regulations and legislation. At that time, Article 7 of the Public Service Law (still in existence today) was created. It's a one-stop siting process for transmission in New York State. Gene happened to be there, right at that time.

Next, he went on to General Electric (GE) for a number of years and rose in the ranks of a real blue-chip company that was reinventing itself. Under Jack

Welch's tutelage, as you all know, GE became a stalwart company of the 1990s.

Gene came back to state service for the New York State Public Service Commission in 1995. He became the deputy commissioner the following year, just as New York State was moving into the competitive market.

He came to the New York Power Authority in 1997, at a time when the Power Authority was having its own bumps and problems with deregulation. One of his major accomplishments was the selling of nuclear power plants at a market price. You may know that many of these old power plants were viewed as stranded assets, but not in New York State. The Power Authority sold those power plants at a good price, which changed how the market responded to that type of transaction.

Without further ado, I will introduce Gene, who stands head and shoulders above the rank and file, both literally and figuratively!

Eugene Zeltmann

Thank you very much, Kevin. It's great to see all of you here today. You heard a terrific introduction about Saratoga, and if you get an opportunity, try to see the battlefield. It is a jewel. It is one of the smallest national parks in the United States, yet, it's an extraordinary experience.

On behalf of Governor George Pataki, I am happy to welcome you all here to Saratoga. I noticed as I looked at it this morning, the agenda for this meeting is full. You'll have a chance to do a lot of exploring, and you'll have an opportunity to hear a lot of terrific talks and analyses. The Power Authority is delighted to be one of the major sponsors of this event, and given my ties to EPRI, I'm extremely pleased that EPRI is also a major sponsor.

The Power Authority owns and operates about 1,400 circuit miles of transmission lines. Our system includes about one-third of all high voltage transmission in New York State; therefore, effective rights-of-way management is key. Further, it is critical to our overall survival.

The blackout of 2003 has focused attention on this matter in many, many ways, certainly for the Power Authority, as well as throughout the electric industry. The US–Canadian Power System Task Force identified inadequate tree trimming as a major initiating cause of the blackout and of several widespread power failures in previous years.

These findings are being taken seriously in the electric utility industry and by public and regulatory officials at both the state and federal levels. It's clear that rights-of-way management issues, particularly vegetation management issues, are going to be front and center for some time to come.

Shortly after the Task Force report was released last April, the trade publication "Engineering News Record" noted that the group's recommendations had focused on four "Ts": Tools, Training, Transmission assets, and Trees. It occurred to me that in many ways these elements form the backbone of the Power Authority's strategy for our 16,000 acres of rights-of-way that require vegetation management.

Tools. One of the most important tools is the Geographic Information System (GIS) that we began implementing in 1999 and that is now virtually complete. GIS provides the ultimate in panoramic snapshots and digital mapping. It shows the location of all of our transmission facilities, the status of vegetation treatments, vegetative growth, identifies some types of vegetation, sensitive environmental areas, and much, much more. I'm extremely pleased with the innovative use of this system that has earned a 2004 Special Achievements in GIS award, better known as SAG, from the GIS software developer Environmental Systems Research Institute.

Later this morning you will be seeing a DVD presentation using GIS. On Thursday morning, you will hear John Wingfield of the Power Authority staff discuss our GIS program in greater detail.

At the Power Authority, we've also centralized our vegetation management efforts, which had previously been carried out by staff members in individual power projects. In 1998 we appointed our first system forester, Kevin McLoughlin, and two years later we created a Transmission Maintenance Group, giving the system forester responsibilities for all rights-of-way environmental activities, including vegetation management.

Then in 2001, we began a new program calling for all lines to be treated on regular four-year cycles. Previously, work had been done on an as-needed basis as determined by visual observations during routine field inspections.

Training. The Power Authority provides funding and manpower for statewide training of certified pesticide applicators. We also provide additional training to our contractor work force so that new applicators can become eligible for certification as apprentices.

Our commitment to training is complemented by our sponsorship of national and state research on rights-of-way management. The Power Authority has been a member of EPRI's ROW Environmental Management Research since 1998. We also worked with the State University of New York College at Oneonta to do ongoing detailed environmental monitoring at specific right-of-way sites. Two years ago, we joined a consortium of New York State utilities that is co-funding a $1.4 million dollar right-of-way field research program by the State University of New York College of Environmental Sciences and Forestry.

Transmission assets. Here, I will focus on the Power Authority's convertible static compensator, or CSC, completed this year. This was a function of our work on the flexible AC transmission system (FACTS), which is located in the Utica–Rome area. It is the world's largest, most advanced device for controlling voltage and power flows on existing transmission systems. The key words here are existing transmission systems.

The CSC, which is featured at our booth in the exhibit area, has increased the capacity of the New York State system by nearly 200 megawatts. If it were possible to put enough of these devices in place, the need for new or upgraded transmission lines could be postponed. The beauty of this system is that we get additional flow between Albany and Utica over existing lines. The system senses those lines that are less loaded, sends power across those lines, and thereby reduces the strain on overloaded lines. As a result, the need to add a power line is eliminated.

This could be a pretty good formula in its own right for appropriate vegetation and efficient vegetation management, which brings us to the fourth "T".

Trees. Trees, and specifically their selective removal, will always be central to our overall strategy. Our integrated vegetation management program is intended not only to eliminate tall-growing trees that threaten reliable power transmission, but at the same time, it is also designed to promote the growth of stable, compatible vegetation. These plant communities, known as low-growth communities, inhibit the return of undesirable trees while providing numerous environmental benefits in their own right.

We rely on the judicious application of low-volume herbicides and various other cultural, physical, and biological methods, which we think is a cost-effective approach that will reduce the need for further maintenance. In 2002 we became a member of US Environmental Protection Agency's Pesticide Environmental Stewardship Program, enabling us to share our ideas on integrated vegetation management with others interested in rights-of-way issues.

Those are really the four "Ts": Tools, Training, Transmission assets, and Trees, courtesy of "Engineering News Record."

I would suggest there's a fifth "T", and that is Talk. Perhaps communication is a more accurate and dignified term. I'm referring here to the communication with landowners on the transmission rights-of-way. Communication is particularly important to us because we rely on easements for virtually all of our right-of-way property.

Each year, before beginning the vegetation treatment program, the Power Authority advises affected landowners of upcoming work. Typically about 90 percent have no comment, but those who do express concerns are contacted by mail, telephone, e-mail, or in-person visits. We also solicit landowners' thoughts on the most appropriate vegetation management measures and activities they can utilize to help us achieve our goals.

These communication efforts are a key to the Power Authority's integrated vegetation management program. Through this program we are meeting our objectives while respecting the delicate balance between energy and environmental concerns—a very narrow path, indeed. We realize that we have a great deal to learn from many people and that everyone can profit from the experiences and expertise of others. This symposium offers a terrific opportunity to do just that, particularly at a time of increased public consciousness and appreciation of successful rights-of-way management.

It's terrific to see all of you here today. I appreciate the opportunity and invitation to be here, and I hope you have a great time here in Saratoga Springs. Thank you.

KEVIN MCLOUGHLIN DISCUSSES A GIS VIDEO

Kevin McLoughlin

Thank you very much, Gene. Gene was actually wearing two hats up here. He is the current chairman of EPRI's Board of Directors, so Gene represented both the New York Power Authority and EPRI today. Again, thank you, Gene.

Next on our agenda is a GIS video.

[Kevin McLoughlin discusses the video which provides those not familiar with New York a quick introduction to the terrain and land use from a GIS perspective for each of the stops on the technical field-trip tours planned for Tuesday.]

Eugene Zeltmann

Great job, Kevin. This unique application of GIS demonstrates yet again just how flexible these systems really are.

BIOGRAPHICAL SKETCHES

Lawrence P. Abrahamson

Lawrence Abrahamson, Director, Salix Consortium, and a senior research associate at SUNY-College of Environmental Science and Forestry (SUNY-ESF), holds a B.S. in Forest Management from Michigan Technological University, and an M.S. and Ph.D. in Forest Entomology from University of Wisconsin–Madison. Prior to joining the Faculty at SUNY-ESF in 1977, he worked for nine years as a research scientist/pesticide specialist for the USDA Forest Service in Stoneville, MS, Atlanta, GA, and Ogden, UT. He worked for 2 years with the Applied Forestry Research Institute, SUNY-ESF, Syracuse, NY, on applied research in the fields of forest entomology and pathology as well as with herbicides in silvicultural use. For four years he was the Director of the Northeast Petroleum–Forest Resources Cooperative (NEP–FRC). Presently, he has a joint appointment between the Faculty of Forestry and the Faculty of Environmental and Forest Biology at SUNY-ESF and is Director of the Salix Consortium, Syracuse, NY. Dr. Abrahamson conducts applied research in the fields of forest entomology and pathology, and high-yield wood energy crops as they relate to problems in the State of New York. He has completed research projects with *Scleroderris canker* (fungus disease) on conifers in New York; red pine scale studies in New York and Korea; evaluations of integrated pest management systems for gypsy moths and other forest insects; herbicide use on forest tree nurseries in the western plains and northeast; and silvicultural management through use of herbicides and fire. Presently, he is engaged in research projects involving pest management (vegetation, insects, and diseases) in intensive culture of fast-growing hardwoods (hybrid poplar and willow); vegetation management and plant dynamics on electric utility rights-of-way in New York; and the development of high-yield wood energy crops (willow dedicated feedstock supply system). As director of the Salix Consortium, he is responsible for leading the research team in commercializing willow energy crops.

John W. Goodrich-Mahoney

John Goodrich-Mahoney is a Senior Project Manager in the Water and Ecosystems program area of EPRI's Environment Sector. He manages two research programs: one addressing the risk to human health and the environment from the release of metals from coal-fired power plants to the aquatic environment, and the other addressing ecological and technological issues associated with the development and management of transmission and distribution systems. His research activities focus on water quality criteria development and assessment; model development to assess metal toxicity to fish to reduce compliance costs; transport and fate of mercury in the aquatic environment and the further development of the Dynamic Mercury Cycling Model; development of integrated vegetation management to reduce vegetation management costs and outages; development of remote sensing technology for more real-time assessment of transmission rights-of-way conditions; and development of information to reduce interruptions and outages on distribution systems. He also developed and manages an innovative research program on the use of constructed wetlands and other passive technologies for the treatment of wastewater. Before joining EPRI in 1990, Mr. Goodrich-Mahoney worked at the U.S. Environmental Protection Agency in Washington, DC, the University of Wisconsin–Madison Water Resources Center, and the Woods Hole Oceanographic Institution.

Mr. Goodrich-Mahoney received a BS in geology from St. Lawrence University and a MS in geochemistry from Brown University.

Kevin T. McLoughlin

Kevin McLoughlin retired from the New York Power Authority in 2004. Prior to his retirement, he was the system forester and a consultant to EPRI for the ROW Environmental Management Target. Formerly, Mr. McLoughlin was Administrator for Land Use & Industrial Waste Programs for the New York Power Pool and concurrently, Research Program Manager for the Empire State Electric Energy Research Corporation. Mr. McLoughlin earned a B.S. in Natural Resource Management in 1971 and an M.S. in Environmental Management in 1975 from the State University of New York College of Environmental Science and Forestry, Syracuse, New York.

Scott Leuthauser

Scott Leuthauser is Vice President of Distribution Investment Management for the National Grid Company where he is responsible for the planning and asset management of National Grid's electric distribution and natural gas delivery facilities, including engineering planning and capital resource allocation prioritization. He has held previous positions as Director of Energy Transactions, including rates, power contacts, and supply planning. Mr. Leuthauser is a licensed engineer in New York State with a master's certificate in Power Systems Management, an M.B.A., and a B.S. in Mechanical Engineering.

Eugene Zeltmann

Gene Zeltmann is President and Chief Executive Officer of the New York Power Authority. He was originally appointed President and Chief Operating Officer of NYPA in September of 1997 and then appointed to serve as Chief Executive Officer in April of 2002. Prior to joining NYPA—the nation's largest state-owned electric utility—he was appointed by Governor George E. Pataki to serve as a Commissioner of the New York State Public Service Commission (PSC) in December, 1995. Commissioner Zeltmann was named Deputy Chairman of the PSC in May of 1996.

At the Power Authority, Mr. Zeltmann has been a strong advocate for expanded research, development, and implementation of energy efficiency measures. He is currently chairman of the Board of Directors of EPRI. Before his tenure in state service, Mr. Zeltmann had more than 20 years of international trade and government relations experience as an executive with the General Electric Company.

From 1970 to 1971, Mr. Zeltmann served under the PSC Chairman Joseph Swidler, with emphasis on environmental and energy regulation. Mr. Zeltmann graduated with honors from Beloit College, earning a B.A. degree in chemistry and political science. He later received a master's degree and doctorate from Johns Hopkins University in physical chemistry.

Peter A.A. Berle, Keynote Speaker

INTRODUCTION BY MR. ZELTMANN

Eugene Zeltmann

This morning I have the special privilege of introducing our keynote speaker, Mr. Peter Berle. I met Peter Berle back in 1971 when he was a New York State Assemblyman and an Alfred Smith Fellow at the Public Service Commission. I'm happy to say that we've been friends ever since. During that period, Peter has been involved in almost every major environmental issue that has appeared on the national agenda and on the agenda of New York State. In addition to serving as a state legislator, he has been an environmental lawyer in private practice, Commissioner of the New York State Department of Environmental Conservation, and President and Chief Executive Officer of the National Audubon Society. Moreover, he's served on numerous federal and state advisory boards.

These days Peter seems to be busier than ever. He is co-vice chair of the Board of Directors of the New York Independent System Operators (ISO), where he also serves as chair of the Governance Committee. The ISO manages the state's transmission system and holds the power market.

He and his wife run a sizable farm operation in western Massachusetts and he's the president of Sky Farm Productions, which produces environmental programming for public television. In addition to teaching and lecturing, he does a weekly environmental program on Albany public radio.

Peter is a graduate of Harvard College and Harvard Law School and holds distinguished honorary degrees from several other institutions. His career has been dedicated to protecting and enhancing the environment for fellow citizens and for future generations.

We're honored to have you with us this morning, Peter. Please welcome Peter Berle.

THE FOLLOWING IS AN EDITED TRANSCRIPT OF THE KEYNOTE SPEECH

Peter A.A. Berle

Good morning, and on behalf of the New York ISO, let me welcome you all to the State of New York.

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

I'm honored to be able to talk about rights-of-way. My first experience in this area related to a time when I was a first-year associate at a big Manhattan law firm. We represented a pipeline company undertaking major initiatives such as mergers, acquisitions and financing. The firm did not generally become involved in the undertaking of running a pipeline, but it turns out that on this occasion, we became engaged in a major construction effort to build a gas line from somewhere in the southwest to the northeast. Our firm was called upon. We were the nearest lawyers to the foreman of the pipeline construction crew when he found himself in jail in New Jersey.

We went and bailed him out from this small town jail. He was fortunate to be in jail because, had he been walking around, he probably would have been the target of counterinsurgency! The townspeople were pretty upset. This foreman and his crew of diggers and welders marched through the front yard of one of the prominent citizens in that town and wrought incredible destruction as they went. They had no permit, no right-of-way, none of the legal stuff one would think would go with building a pipeline.

This gentleman was the best in the business. The reason he was so good was that, once he got rolling (in this case, starting in Oklahoma), he could move a project faster than anybody. Utilities loved him because his approach cut costs.

On the other hand, he was arrested for trespassing. Being somewhat skeptical about our chances in a local jurisdiction, and in preparing him for trial, we asked, "by the way, have you ever been arrested before?" He replied, "Oh, sure, 28 times for trespass." We decided not to put him on the stand. We pled guilty and paid the fine.

That story represented a time 40 years ago when people moved perhaps a lot more freely than they do today, a time when some of the mechanisms for working these things out were not as refined as they are today.

We are here today because of our common interest and concern in keeping the lights on. Of course, the situation was accentuated by the trees in Ohio, an occurrence that sparked a whole round of new thinking and new studies. Indeed, national attention has now been drawn to the whole question of rights-of-way management, an issue much more substantial than tree trimming.

We must realize is that there's no quick fix; there's no single solution. This process is continuous, and it will go on as long as there's a need for the transmission of energy—whether it is gas or electricity. It is worth looking at some of the conclusions about this process made by the Department of Energy in one of their recent transmission studies.

First, the study pointed out that our generation capacity for electricity has been increasing at about two percent a year, which is more or less in line with the national demand. However, investment in transmission has been nowhere near sufficient to keep up with demand. We are not building enough capacity on the transmission side to keep up with what is happening with respect to generation. We are building into our planning an increasing lack of capacity.

Second, the study pointed out that the economics are not necessarily working in favor of transmission. With respect to integrated utilities, those companies owning both the generation and transmission, there can be an economic advantage in restricting transmission capacity. An advantage occurs in restricting expansion if it permits a load pocket to be created, thereby enabling the utility to maximize market price at the point of delivery.

The economics of operation and maintenance tend to frequently work against the provision of adequate transmission. In regulated situations, history shows that savings are achieved by spending less money on maintenance. Let's look beyond some of the technical aspects of right-of-way situations. I would argue that we also have to pay attention to the underlying economics. At the moment this is our challenge and work needs to be done.

Reviewing the FERC paper of September 7th, which stems from the analysis that took place after the August event last year, a series of recommendations were generated with which most of you are familiar. The paper discussed mandatory reliability standards, better coordination with land managers, collaborative work between the utilities and communities, and the necessity of better understanding with respect to the problems related to transmission. Clearly this took a lot of time. It was obviously the result of serious inquiry based on the August event, but this is not rocket science.

Indeed, looking at the recommendations, one comment we have all been talking about is the need for uniform standards. Unfortunately, our present federal system is close to paralysis. The partisan fights in the Congress, the differences between the administration and the legislators, and the insistence on bill riders indicates that mandatory standards won't be seen for some time. As a result, it's up to the rest of us. We need to come to as much agreement as we can with respect to standards, and then see to it that they get applied.

I would argue, for example, that CEOs and people responsible for transmission who are not working hard to maintain the reliability standards that now exist ought to be fired. Otherwise is simply not tolerable. It's easy to say "Well, the feds haven't come down with a standard," but we have responsibilities that need our attention. In this day of corporate disconnect, there ought to be increased accountability to meet the standards necessary to keep on the lights.

The other interesting thing about the FERC paper is that it focuses on the procedural items needed to deal with problems that arose last August. It does not discuss how to deal with the kinds of impediments and opposition that arise when dealing with transmission problems. It addresses better coordination between federal agencies, but it really doesn't "get to the guts" of the kinds of problems that many of you face every day concerning maintenance.

To look at those items, please join me on a hypothetical flight of fancy. Let's talk about a circumstance in which the geography that I will describe is real, the places are real, but the scenario is hypothetical. Imagine a situation in which a power line parallels a river through a forested area. It comes out of the forest, crosses a farm, and goes by a village. Indeed, this is the geography of part of our farm. On the five-year maintenance plan, the managers of the power line meet with land owners to discuss what they're proposing to do—that is, repeat the herbicide program used in previous years, without much controversy. The Board of Directors of the local land trust, which holds a conservation restriction on the forest land, is called. Relations have always been good in the past. The manger says, "I'm going to come to your monthly meeting," which is simply the six member board of trustees, "and I'll describe to you again what we're going to do." So, the land trust plans its meeting in the town hall.

As the land trust secretary types out the meeting announcement, he notices that herbicides are involved. This piques his interest because he's a member of the local chapter of Trout Unlimited. He calls his Trout Unlimited colleagues and says, "They're going to start spraying chemicals near the river again. You guys all ought to be interested." Trout Unlimited is concerned, produces an item for their newsletter which says, "Come to the meeting. We've got to stop these fellows from the power company. We think they ought to handle this problem with chain saws."

Suddenly, the movement-to-bring-in-chain-saw-crews is out. A wife of a Trout Unlimited person is a member of Elm Watch, which is the group that is dedicated to preserving a few of the great ancient old elm trees in the community. It's speculated that if chain saw people are out, they're probably going to widen the right-of-way in anticipation of future expansion. This puts the Elm Watch people into a panic because, indeed, one of the century elms that they are dedicated to preserving at all costs is right at the edge of the farmer's field next to the power line. Elm Watch newsletter prints, "We've got to go to the town hall to save the elm," which then activates their telephone tree.

Once that gets going, the farmer remembers that he read something to the effect that cows, under high voltage power lines, have trouble settling. He notifies the Farm Bureau; they say the only thing to do is have a moo-in, bring a few cows in a trailer to the town hall and let them out. All this talk about settling cows ultimately wakes up both the Planned Parenthood people and the Right to Life people; they realize they have a real stake in this, too.

Now, back in the village is the music teacher in the junior high school. He gives violin lessons at home. He heard that once you have more power going through a high tension line, you get noise. He's worried because he thinks this is going to interfere with his ability to give music lessons in his home. He takes his six squeakiest ten-year-old violin players and asks them to come to the town hall to play "God Bless America" as the fellow from the power company arrives. And, there are some builders and cross-country skiers that have some opposite views about what to do with the power line. Of course I could go on and on. The lawsuits haven't even started yet!

The fellow from the power company shows up, sees the mob at the town hall, gets out his FERC manual to see how he might handle this, based on the latest direction from Washington, and finds that neither counterinsurgency nor counterterrorism are even listed in the manual. So this poor guy is in quite a situation—one that I know that some of you have witnessed first hand. Even before the process begins, the power company finds itself at odds with farmers, expectant mothers, tree lovers, you name it.

What does this tell us? There's no end, even in a small community, regarding the number of interests that can be triggered. Every element in the community is out there, and yet, all of those elements have a common interest in keeping the lights on.

There are some things that need to be said about how this system works. The first is that, we, as a community trying to deliver and generate power, have not been very good at broadly communicating the needs of the community and of the system. If needs are only communicated at the time of the crisis, there is no underlying sense of the kind of understanding that is necessary in order to create an acceptable solution. Each year, the ISO discusses what it sees as needs, particularly on the generation side. This is intended to get people to understand the issues and to continue thinking about how to solve these problems.

Continuous communication is the underlying issue, and it needs to be done fairly. Recognizing there are numbers of ways to solve these problems is important—distributed generation versus transmission; one form of control versus another; and there is no single textbook solution. Different solutions work in different applications. That's hard to understand and implement when there's a huge task with a pressing timeline.

There is another issue. Once a decision is made, we must ask if the solution is really viable. Is it one that may or may not be the most cost effective, but that basically meets the largest number of the communities' concerns, recognizing that those concerns are not uniform? People have different perspectives and different values. Then the question becomes, when one has to decide between those, are some more important than others? If the concern is potential birth defects from chemicals, that ranks as a much higher priority than lowering the risk of an outage.

Additionally, perception and understanding of risks are constantly changing. As Commissioner, I dealt with the problem of PCBs from GE. When GE started putting PCBs in the river, PCBs were not regarded as toxic or even an environmental hazard. They were considered to be inert. It was only in the 1960s, when a barrel of PCBs got mixed with a barrel of rice oil in a community in Japan and people started losing their hair and getting rashes. Only then was it realized that ingesting large amounts of PCBs is not good for one's health.

Consequently, in trying to eliminate PCBs in New York, prior to the federal government's involvement, GE quite properly said, "Look, we put them in the river because the State of New York gave us a permit to do it. We met our permit requirements, and so we thought it was okay."

We said to GE, "You violated your permit because, even though you were allowed to put PCBs in the river, the fine print said you can't put toxins in the river. Once you realized they were toxic, you shouldn't have put them in the river." GE came back and said to us, "You knew they were toxic at the same time we did. You didn't pull the permit."

Those are the kinds of situations that enable lawyers to make a living, but it's a long and tough process. The point being, when science and technology changes, or our understanding of them changes, our systems have to change too. We have to engage in systems that can recognize new facts and are able to accommodate them. To whom and how to allocate responsibility for that cost are ongoing issues.

We also have to realize that when it comes to risk, different people perceive risk differently. I mentioned the balance between risk of an outage and risk to an unborn child. There are people who are prepared to say, "I will assume a higher risk of power failure because of some other value I perceive to be at least as important." The risk issue, and how to evaluate it, is one of the core challenges of our time. And, there will never be a uniform response.

The question is, "How do we set up procedures to meet our needs?" I suggest that who is the ultimate decision-maker becomes a critical factor. For example, the judgment from a Dow Chemical salesman will differ from a neutral research institution or even the local conservation commission. Decision-makers vary and judgments are made sometimes by companies, sometimes by regulatory agencies, sometimes by the courts.

All of those decision-makers can get involved in a single right-of-way issue depending on how far up the ladder it progresses. It would not help matters to have the process strung out forever, but there are people who have to live with these rulings. Important decisions must be made by respected decision-makers. It would be great to have the process be as fluid and as simple as possible. The decision that actually sticks, in terms of credibility, is not always an easy one.

As you think about some of the technical aspects that you're going to be working on in the next few days, I hope you keep in mind the fact that: a) there are no simple solutions, b) this is going to be with us forever, and c) we need a decision-making process that engages as many people as possible, and engages them early on so that their views are taken into consideration before they become barricades. Because once that happens, it's a free-for-all. It's a lot of fun, but it's not a very efficient way to get things done, nor is it necessarily the means to find the most relevant solution.

One final comment: it seems obvious, but for those that are engaged in this process, it is critical that you play according to the rules.

My law partner, Al Butzel knows this very well. He basically stopped the Westway Project in the federal courts. For those of you not familiar with it, this is a highway that was going to go down the west side of the lower end of Manhattan, past where the World Trade Center used to be. It was going to fill in part of the Hudson, and solve a lot of traffic problems and create land for development.

Opponents said, "We should be spending the money on mass transit instead." "This may damage the Hudson." "It's a poor allocation of resources." There were some genuine issues on both sides. The matter finally ended before a federal judge relating to the adequacy of the Environmental Impact Statement (EIS). There were some technical problems and Al thought he could make some hay with them. During the course of the proponents setting out the case, they put on the stand the fellow that had drafted the conclusions of the EIS. One of the questions asked was about the impact on striped bass. (This issue had been a major cause of the ultimate demise of the pump storage plant on Storm King Mountain.) In the introductory questions, Al asked this witness if the EIS conclusions relating to the impact of the project on the Hudson River fishery, striped bass in particular, were his. He replied, "No." Al took two steps back and said, "Well, why did you put them in there?" His answer was, "They told me to."

Here was an honest man. The federal judge stopped the proceeding and gave the complainants another round of discovery. This round of discoveries found memos back and forth saying, "Can we put the fish studies in your files so they can't be reached when this issue gets challenged?" Consultants were less sophisticated in those days than they are today. The point is that this is still looked at as a big environmental case. In fact, it was not. It was fraud in a government case; and that's ultimately what defeated it. I think, even though the project was a disaster for a lot of public policy reasons, it probably could have been built if the fraud issue had not been there.

I'm saying to you that you've got to play according to the rules. You can't suspend part of the regulations to get things done; that's trouble and a blueprint for disaster. Fortunately, we live in a society where there is not much tolerance for this type of behavior. Bad things happen: CEOs loot their companies, people cheat when it comes to buying and selling stock, but at the end of the day, we have the strength of our people. People are the best self-righting mechanism.

This is a basic principle. You can't cheat at the game and expect to get away with it.

Good luck to you, and I hope this is a productive conference for everyone.

BIOGRAPHICAL SKETCH

Peter A.A. Berle

Peter Adolph Augustus Berle, host of the Environment Show, a public radio and ABC Radio Network program, has been involved in almost every environmental issue that has engaged the nation over the past three decades. During that period, he has been an environmental lawyer in private practice, a state legislator, Commissioner of the New York State Department of Environmental Conservation, and President of the National Audubon Society—one of the nation's oldest and largest environmental groups.

Mr. Berle has served on numerous advisory groups, including the task force on the future of the Adirondack Park, which he chaired for then-Governor Mario Cuomo, on United States Environmental Protection Agency advisory groups for the Clean Air Act, on biotechnology interests during the Bush Administration, and currently, as appointed by President Clinton, on the Joint Public Advisory Committee to the North American Commission on Environmental Cooperation, established under the NAFTA environmental side agreement.

Mr. Berle is a graduate of Harvard College, Harvard Law School, and has been awarded honorary degrees by Hobart Smith College, North Adams State College, Long Island University, and Southern Vermont University. He is a member of the New York State Bar Association, admitted to practice before the federal District Courts in New York, the United States Court of Appeals for the Second Circuit, and the United States Supreme Court. At various times in his career, he has also served as adjunct professor, teaching environmental law.

Plenary Panel Session: "When the Lights Go Out: Environmental Choices and Consequences"

Allen F. Crabtree III

THE FOLLOWING IS AN EDITED TRANSCRIPT OF THE PANEL DISCUSSION

Allen Crabtree

Good morning. I'm glad to see such a good crowd. In Calgary we had a panel discussion to set the scene for the theme of the conference. We are doing the same thing this year, with our theme: "When the Lights Go Out: Environmental Choices and Consequences."

The US–Canada Power System Outage Task Force report identified the failure to adequately prune trees and manage vegetation in transmission rights-of-way as one of the four primary causes of the August 14, 2003 blackout—and I emphasize the number "four." There is no simple fix, as Peter Berle commented in his keynote address. Our panel will be discussing some of the inter-relating factors that affect whether or not the lights will go out.

We are facing an energy delivery system that in many parts of the country is loaded or even overloaded. The causal factors of a blackout can be as minor as one tree coming down. But this doesn't mean the solution is just vegetation management; it's a number of factors.

Let me introduce our panel, whose biographies are available in your program. Ken Pokalski is the Director of Environmental and Regulatory Programs for the Business Council for the State of New York. Clark Gellings is Vice President of Power Delivery and Markets for EPRI. (He flew in from California to visit with us today.) Marc Mahoney has graciously accepted our invitation to sit in for Jeff Scott who was unable to be with us today. Marc is Vice President of Transmission Network Asset Management for National Grid in the United States. Brooker Holton is an applied ecologist and environmental planner, and President of TOVA Applied Science & Technology. We are pleased that Peter Berle is joining our discussion.

Keeping the lights on is not a situation to which there is a single, simple solution. It is a multi-faceted situation. I hope that our conversations today will give you a sampling of the content of the papers that will be offered in our upcoming technical sessions and in the poster sessions. Many of the papers specifically address factors influencing reliability and keeping the lights on.

Ken, let me start with you. What is the magnitude and severity of the energy supply issues now facing the US, Canada, and Europe?

Ken Pokalski

I'm here today to represent the perspective of the 3,200 commercial and industrial consumers of electric power in New York State who comprise the membership of The Business Council, a statewide chamber of commerce and industry. During the last several years, the issues of electric power supply and reliability of supply, availability of power, and cost of power are rapidly moving up our members' list of priority issues.

I will be addressing our experiences here in New York, but the same issues are coming up nationally, as well. This issue—that electric power is literally the lifeline of so many aspects of the national economy and state economy—is becoming increasingly important. During this conference, you're going to hear often about the disconnect between the growth of demand for power and the growth of the ability to generate and transmit power.

In New York State, between the years 1980 and 2000, the state population grew by about seven percent, cumulative over that 20 year period. If you measure growth in the private sector, employment grew by about 20 percent. Total usage of electric power grew by 30 percent, more than four times the rate of growth of the state population. Growth in peak demand, during that same period of time, grew by 42 percent, six times the growth in population. This is a steady trend line seen over the last two decades, during the years of economic slowdown as well as during years of economic growth. Both total usage and peak demand are rapidly growing.

One of the questions asked is, "Is that disconnect between usage and capacity getting larger or smaller?" In New York, it's becoming significantly greater. Between 1981 and 2000, the growth in peak demand in New

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York State grew by 8,900 megawatts. During that same period, peak capacity grew by 7,900, a gap of 1,000 megawatts. That's over a 20 year period. The growth in peak demand grew by 2,700 megawatts; the growth in peak output grew by 300, almost a ten-fold increase in peak demand over peak output, during the last five years of that 20-year period.

When New York State went through a triennial process of updating the state energy master plan in 2002, the independent system operator (ISO) was projecting a baseline capacity of about 3,600 megawatts, and a need for 8,600 megawatt increase in base capacity by the year 2005. New York State is pegged at 18 percent excess capacity for reliability purposes, a 15 percent excess capacity to assure competitive retail and wholesale markets for electric power, and that projection is on the low side.

New York State is going to fall woefully short of those targets by 2005–2007. Conservation and load management have roles to play. In the short term, with the rapid growth seen in electric power demand, the need for new baseline capacity is the major energy challenge in New York State. This circumstance is seen from colleague associations in other industrial parts of the US, as well.

Allen Crabtree

It doesn't sound like things are getting better in the short term, and the prognosis for the future is equally grim. Is that a fair summation?

Ken Pokalski

Peter Berle's excellent introductory comments today emphasize the point that many different viewpoints must join together to address these issues. Currently, government and industry have not done a good enough job emphasizing the future. We're representing this from a commercial and industrial perspective. Every issue just discussed is equally important to the residential sector, but they probably don't know it. We have the highest residential rates of any state in the continental US, only surpassed by Hawaii and Alaska. Shrinking excess capacity, especially at peak times, directly affects the large industrial consumers using load management and load shutdown during those time periods.

As we've seen in recent history, blackouts and brownouts can also affect us at home. The public sees this as a battle between the interests of the local citizens and those of the people who want to build power plants. I don't think there's a general recognition of the "crisis," to generate and deliver power to the consumers.

Allen Crabtree

Peter, what are your thoughts? Is this a problem that is growing but is fixable; or are we going to have to go back to candles?

Peter Berle

I believe the problem is growing. Of course, it is fixable. The question is, how? In thinking about it from the ISO perspective, we look at what may or may not be done with respect to planning. I'm impressed with the fact that, at least in New York, the Public Service Commission can order the construction of transmission related to reliability.

Allen Crabtree

That's in New York?

Peter Berle

Yes, in New York but the whole question of economic upgrades is different. The first questions are, "Does that make any sense? Is there really a distinction between the two?" Then we must ask, in a deregulated electric market, "Is reliability totally divorced from price?" If the power is always available, but it costs a zillion bucks a kilowatt and most of the consumers can't get into the market, do you really have an acceptable system? Is that system reliable?

I'm suggesting that reliability has a broader dimension. Reliability means more than simply answering, "Does something happen when the switch goes on?" There is also a question of the mechanism by which people access the system.

One example is the increased interest in merchant lines. They can offer great opportunity. On the other hand, they may present a hazard depending on whether they operate for the benefit of the public or that of the shareholders.

Sure, it's fixable. The question is how to produce the best and fairest results for a society in which providing electricity is more than selling a commodity.

Allen Crabtree

Mr. Gellings, what do you have to offer?

Clark Gellings

We have to take a system view. I believe you inferred this, but one must look beyond the traditional mechanisms. You mentioned distributed resources earlier. We have to look everywhere, from generation of the power, to the delivery system, to the end uses of consumer devices and appliances. We could reduce the current demand for electricity somewhere between 25 and 45 percent. Although it is perhaps not yet economical, we could do this now through the use of the most-advanced, energy-efficient devices and appliances.

When reliability or power quality are the issue, often a small fix will work. For example, a $40 ultra capacitor in a programmable $15,000 lathe might mitigate most of the problems in a particular circumstance.

What I don't see uniformly across this nation is a broad look at all of the individual areas of technology, from generation through delivery, distributed resources, and on into and behind the consumer's wall.

Allen Crabtree

Booker, you're shaking your head.

Booker Holton

Obviously, from the environmental perspective, I'm always looking at ways in which we could make better use of what we already have as part of the mix. I'm fascinated by technology. I was talking with Mike Fryer earlier about using technology to collect fuel data. It's fantastic. I was also intrigued by the earlier comments referring to the fact that flexible AC technology and something called high-voltage DC are apparently being used by San Diego Power, and I believe, elsewhere in New England and New York State. To me, it makes good sense. If you could, with a low environmental-impact kind of technology, use existing substations to generate a system that can produce greater efficiency, with built-in smart intelligence, it could also be used to do things like voltage control and so forth.

One of the problems with sources like wind power is uncertainty. Sometimes it works, sometimes it doesn't. It depends on whether or not the wind blows. Something like high-voltage DC apparently makes allowances for that difference and uncertainty. That kind of broad spectrum, holistic approach should be thrown into the mix as we use conventional generation and transmission.

Allen Crabtree

So, Marc, do you think that load management is the sole solution to the problems?

Marc Mahoney

It's one of many solutions and certainly technology is another solution. There is a capacity gap in terms of the amount of generation being planned and built. I would contend that, despite the bleak picture Ken painted of the situation in New York, it appears to me that New York is relatively well off with regard to generation planning. I know we still fall short, but the situation is worse in other parts of the country.

The other side of the equation is the transmission capacity. We're asking transmission systems to do more with less. When deregulation arrived in this region, transmission investment all but dried up. What was needed was just the opposite. As new generators are installed in locations other than the vertical utilities, it puts different stresses on the transmission system.

You would think, with all these new generators built over the last ten years, there would have been a corresponding increase in transmission investment; however, transmission investment declined, and now there are some real bottlenecks, which are only growing.

We must ask ourselves, "Why aren't transmission owners investing more in new technology, new lines, even load management programs?"

Allen Crabtree

Well, why aren't they? Peter spoke about economic incentives, or lack thereof. Is it a consequence of deregulation? Has a monster been created, or is this just part of the dynamic growth and maturation in the energy system?

Clark Gellings

All of the above. The answer is, there's a great deal of uncertainty among utility executives as to whether or not an investment, prudently made today, will be so deemed by some future organization or agency, depending on the regulatory environment. The question is whether it's worth it and if the incentive is there for the individual utility. It's a mess. Earnings pressure is severe.

Ken Pokalski

I think Peter hit on a key point, "Does the system operate for public benefit or for the shareholders?" Add to that the regulatory body's view. Will a utility, who's regulated to serve a geographic area, build transmission capacity if the benefit will be enjoyed by customers outside that area? Should the local area rate payers bear the cost? How do you allocate the cost of this new development between the "host" and the "end user" of the line?

There are many issues such as these that we haven't sorted through, and they will become more important as we move toward a more deregulated utility sector.

Clark Gellings

Look at First Energy. Last August, the day of the blackout, 40 percent of the energy transferred across First Energy's control area had absolutely nothing to do with serving native growth. Where is the incentive for First Energy to invest in additional transmission to facilitate wholesale transmission? It's a complicated situation, but the short answer is, there is no incentive.

Another example is the infamous California Path 15. It's a corridor in California, which for five days in the year 2000, cost the rate payers of California over $140 million a day. The construction of additional capacity would have cost $340 million, but nowhere did the mechanism allow the responsible utility, PG&E, to build a line. The commission basically said, "You shall not spend that money to build this line, because it will not benefit the rate payers of PG&E." The line is located essentially in their service area. It's finally under construction now.

Allen Crabtree

But it took a fair amount, as I remember. Booker and I worked on that. We were involved with Western Area Power Authority, and a few others, on the regulatory hassles and permitting approvals.

Booker Holton

Well, it was a question of who runs the show, really. It was such an impediment that the Transmission Authority of Northern California said, "If you feds, or if you state, or if you anyone else, don't want to do this thing, we'll go ahead and do it in some kind of cooperative manner with the state." So, it went to the federal government. That's when the state and the PSC stepped in and said, "You shall not do that." They defined a mandate that then delayed things for another couple of years as a result.

Allen Crabtree

Well, let's save those thoughts about a regulatory fix. To summarize, I'm hearing you say that there is a problem. It is increasing and will continue to increase. We have a difference between demand and supply, but mostly the concern is delivery. There are some solutions, both engineering and technical, but there is a need for an overall plan to fix the problem. Further, there are some inherent problems that must be overcome, particularly in terms of regulatory constraints and economic disincentives.

You've seen the report about the blackouts caused by a lack of danger tree removal. That should be a fairly simple thing. What's the problem? Do current environmental regulations, as well as industry requirements, handicap construction and maintenance activities?

Booker Holton

I'm going to give you a "yes, it does; no, it doesn't" answer. In terms of regulatory constraints, it depends on the project. Peter had a very interesting point this morning when he said that it depended on the particular vantage point produced by each interested party's perspective.

I think the rules are there. The rules have been there for some time and they will continue to be there. The public will make sure that they are. And, as Peter said, we have to play by the rules. But is it that easy? I think impediments to projects boil down to communication problems between project proponents and regulators. There's a lack of effort before the actual planning stage to educate or contact the public in order to gauge their concerns. We are afraid of public involvement. We are afraid of letting the public know that a project will take place.

There are some problems involved in planning, because there are security issues as well. How much do we map? How much do we tell the public? We have to make sure the plans are well thought out and well documented. Often there is fuzziness about what truly is a mitigation measure. I think it has to be well thought out, and it has to be dealt with by both the state and federal regulators prior to actually signing on the dotted line.

I also think there is distrust between the public and the energy sector. In California, there has been a tremendous amount of distrust because of deregulation. No one knows what's really going on in that sector.

Some initiatives for streamlining that have been started in the West probably should be duplicated. The president's executive order of three years ago is very difficult to implement. There are a number of memoranda of understanding and protocols that have been set by the Western Governors' Association. There is a memorandum of understanding between the governors of these participating states and the federal government to effect a streamlining, so that if there are any delays, they are not from the federal regulatory side. Rather, it's a delay on the industry side: a lack of proper information, a lack of clear mitigation measures clearly spelled out, those types of things. It depends on the project, of course. Sometimes projects are very complex and that involves a lot of time delays. As a result, the regulations are blamed.

Allen Crabtree

You mentioned an industrial role. Would a more proactive industrial role help?

Booker Holton

I think so. This whole ISO 14001 concept, which has probably been forgotten, is a good point. Industry has to show every step of this operation, from project planning, to project operation, to maintenance. The transparency has to be at the corporate level going all the way up to the CEO. I agree that if a CEO does not practice what's in the company's environmental policy statement, he should be fired. I think that it should be part of corporate culture to have this kind of environmental sensitivity.

Marc Mahoney

I represent a transmission owner, and I don't necessarily disagree with what Booker just said but I want to elaborate. Let me engage the audience here for a minute and ask, "Do we all consider ourselves mature adults?" One of the hallmarks of a mature adult is someone who is proactive. A mature adult, being proactive, is not one who blames all of his problems on something out there. In other words, if a project is delayed, or is not getting sited properly, or there's a seemingly deleterious order of conditions that we have to live with, I would contend that it's our fault. It's not the fault of regulation. I don't think regulations handicap what we're trying to do in the transmission business.

What it does mean, however, is that we have to be better planners. We have to factor the regulatory process and the regulatory schedules into our long-term planning. We have to do better long-term planning and live with these schedules and this process. Also, in terms of being proactive, we have to be out there trying to shape regulations and work with the regulators and scientists and others in the industry to make the regulations smarter.

Allen Crabtree

Well, Peter, let me go back to your illustration at Berleville, where we have a number of people closely focused on their greatest individual needs and desires. They are not necessarily being proactive in looking for a solution as much as they're protecting their particular interests. If you were the industry representative walking up the steps to the town hall that night, how would you be proactive and deal with this group of people? How would you implement the concepts that Marc and Booker have advanced?

Peter Berle

First of all, let me back up to comment about an issue that you mentioned. That is, "How do we feel about changing environmental regulations to meet specific crises?" It is a legitimate question. My first reaction to that was, suppose you're in charge of rebuilding the World Trade Center. You must meet a deadline for a whole host of reasons. You can't find structural steel of sufficient capacity to build to specifications. You would not say, "Let's relax the standards on structural steel so I can get this thing done in a hurry."

Allen Crabtree

Fair assumption.

Peter Berle

Of course. It's appropriate to look at environmental regulations in the same light. There may be regulations relating to steel which don't make much sense, and don't improve performance. This is of course true in environmental regulations, but those are the last to need review. We must begin reform efforts with two assumptions. First, the regulations in question were designed, at that time, to achieve a specific objective. Second, it was the best solution at that time. Having a regulation means there was a process in which interested parties sat around a table, talked about the issues, and came to an agreement about the best solution. It's painful and it's time-consuming.

I remember a proceeding through FERC when the objective was to establish regional transmission organizations (RTO). The idea of looking at an integrated system is something that had not been done before. We wondered how we could get it all to work together. After a whole summer of work, it seemed that nobody got anywhere. The process that summer amounted to identifying issues and getting them out on the table. But if a process gets that far, it is not fair to say nothing was accomplished. And, indeed, there are solutions.

You can say, "Well, I can solve this by having everybody buy a washing machine that costs twice as much but uses half as much power." It looks good on paper, but explain that solution to somebody who considers it a luxury to have a washing machine at all. It's hard to implement. One of the concepts that can never be far from our minds is, "How vital is all of this?"

If you've got the mob in front of you, you've got no choice but to sit down and talk to them until you get to a point where there's enough agreement that, when you finally do get something done, either by order or other means, people won't be inclined to sabotage the project.

We tend to assume that we live in a society where that kind of thing doesn't happen. Early in my legal career, in the late '60s, early '70s, I was involved in representing the Alaska Federation of Natives with respect to their land claims in Alaska. Suddenly those land claims became important because oil had been found. Everybody wanted to claim land they thought might have oil on it. That included the state, the natives, and federal interests. In the course of all this, the discussion of the pipeline came up. There were engineers, and environmentalists, and all these folks talking about the pipeline. The natives, who had been hunting, fishing, and running this route for generations, were sitting on one side of the room. At one point one of them said, "You know, if this gets too bad, we can take that thing out with a high powered rifle." He meant it and everyone knew he could do it. A solution is only a solution if people can accept it.

Ken Pokalski

There are so many issues we've touched on. I want to offer a couple of comments and observations from my experience.

I agree with Peter. By no means is our organization advocating for a relaxation of existing environmental regulations. That's not to say that the body of regulations, as it currently exists, is as effective, efficient, or appropriate as it could be.

For example, there is the national debate over the pre-construction "new source review" of power plants. It's an incredibly complex program. It has gone through several major rewrites in New York State. Our state Department of Law represents one of nine attorneys general suing the federal government on new source review. Nevertheless, there is always room for common ground. While working on this process, I was struck by the strength of the response from the environmental community over the reforms that the federal administration adopted. I'm not going to argue that the rules are perfect. There are some areas that are decidedly less than prefect, and as states implement what the EPA has written, some of those deficiencies will be ironed out. Even so, our conversations with the Department of Law and the Department of Environmental Conservation (DEC, the regulating entity in New York State) reveal a fair amount of agreement over some of the headline issues. There are some ways that the program could be streamlined and for certain types of projects, it could even reduce the review time.

It seems in the immediate response to an issue, the public and business are equally guilty of highlighting the most extreme concerns. However, when we step back a bit, our vision improves and we can give a complex issue more specifics. Certainly, there are areas of agreement on ways to improve an existing body of regulations to assure protection of the environment, but there are also reforms that can make the regulatory process more efficient and less expensive.

In terms of being proactive, there are two experiments going on, one at the national level and one at the state level. One is the National Performance Track Program, where the EPA is trying to match regulatory review with what I'll call a "transparent process," by which regulated entities demonstrate high levels of performance and high levels of environmental stewardship. The basic requirements of being a federal performance track company are a high level of compliance with environmental laws and a specific commitment to going beyond regulated environmental improvements at one's facility and properties.

Regulatory relief at the federal level, in a state like New York, is not much help because most of the federal programs are delegated to and run by the DEC. New York State is taking steps to have a regulatory apparatus become either linked to, or at least associated with, this national program. It's something that our corporate members find very attractive and from what I've seen so far in New York State, it has not only received a positive response by regulators and business, there is also a fair amount of interest from the environmental community as well. This makes sense. This can be one of those win-win situations that everyone is looking for.

Allen Crabtree

What I've heard so far is that we need to play by the rules. Rules are on the books; they're there and we need to acknowledge them. It certainly will help if industry and all the players are proactive in seeking a solution. Communication is terribly important, so we need to involve all the stakeholders in this process early on.

Finally, there is an opportunity to streamline regulations, to focus on those that are important, and to come up with a system whereby the others can be smoothed through. That's all well and good if you're building a transmission line in California or you're building a transmission line in New York State, but we've also heard of the need to coordinate with different authorities. What am I going to do if I'm building a pipeline or transmission line that stretches across several states? While we're at it, let's bring some gas down from Canada across the international border. We are dealing with a plethora of state, provincial, and federal authorities, all of whom are protective of their regulatory turf. Who has a nice, quick, solution for that? Is it an RTO?

Booker Holton

This situation is being addressed in baby steps. For example, there are protocols and memoranda of understanding with organizations such as the Western Governors' Association (representing many jurisdictions—state and local). These efforts are working toward an established protocol that can be applied during review of transmission projects. Such a protocol would use an agreed-upon set of standards intended to smooth operations among federal regulators such as Department of the Interior, USDA and EPA.

These activities demonstrate participants' desires to engage in a meaningful set of discussions. It is a process they all want and they all think should take place in a cooperative, streamlined fashion. But of course, with a bunch of transmission lines crossing state boundaries, there are problems. When is the agreement initiated? Who pays for it? Will there be a cost-reimbursement strategy? Will there be an arrangement to allocate staff time?

Peter Berle

I would suggest that we have made some progress setting up a structure, flawed as it may be, with respect to hydroelectric dam construction. Further, issues relating to eminent domain are clear with respect to pipelines and transmission lines. We are not starting from scratch. It seems to me there has to be a federal umbrella that may or may not be triggered depending on the scope and location of the project. There need to be clear and uniform rules with regard to eminent domain. Yet, the states need jurisdiction to impose higher standards, which may be necessary to protect their unique resources.

Allen Crabtree

Including trespass standards?

Peter Berle

Well, that may not be up-to-date. Let me give you an example. We are right next to Lake George here, which has potable drinking water. People drink the water from the bottom of the lake. When I was a commissioner, there was a proposal to have the US Corps of Engineers' federal standards apply to Lake George. Those standards would not have guaranteed that the water would continue to be potable. A successful protest resulted in an exemption; however, that was a case with a legitimate concern that did not fit easily within federal standards.

At that time, it was much easier to ascertain who does what to whom with respect to transmission. For that reason, I will argue that there's got to be an opt-out under certain circumstances. Our experience in New York, with respect to Article 7, which is sort of a one-stop shopping system for building transmission lines, has worked pretty well for the last 30 years.

Allen Crabtree

Yes, but the world has changed, particularly since 9/11. These changes affect rights-of-way activities, particularly with regard to security and information access. Let me pose this to Clark. As an engineering and safety concern, will today's power-delivery system meet the needs of tomorrow?

Clark Gellings

I think the power delivery system that we have today is in danger of becoming a relic of the industrial age. Let's set aside the under-investment in capacity for the moment. There's another change we need to note: the evolution and proliferation of the microprocessor. At this point, about 12 percent of all electricity use is either into or controlled by a microprocessor—computers, telecommunications, and the like. Today if you walk into an industrial facility, 67 percent of industrial energy use is for motors. Now, most of those motors have a box in front of them called an adjustable speed drive mechanism, which essentially controls the microprocessors, the motor speed, and matches the mechanical output needs of whatever it's driving.

People say there really hasn't been a change in reliability, and if we look back ten years at the 24 states that track this, you'll see that it doesn't look like reliability has changed very much. However, because of the microprocessor and its sensitivity, the response of these end-use devices to any changes in voltage on the system or in frequency is much more severe. We did a rather thorough survey just a year and a half ago of a thousand businesses and industries. We learned, to our surprise, that perhaps as much as $188 billion per year—each year—is lost in productivity as a result of both poor power quality and reliability.

So, what has changed here? The reliability is the same, but the consumers' devices have changed. Today you can't buy an end-use energy-consuming device or appliance, whether household, retail, or commercial, that doesn't have an imbedded microprocessor. These microprocessors not only make use of that device much more efficient, but they also make it much more vulnerable.

As we think about reliability, we also must consider security, safety, and quality. Ours is the only major industry that has not been truly revolutionized by the advent of computational-ability sensors and communications. The delivery system of today will not meet the needs of tomorrow unless we are able to harness advanced technologies to modernize the power system.

Allen Crabtree

So, it's not just a matter of building more hardware?

Clark Gellings

It requires a couple of things. We need to build more hardware and modernize the system. Some of this can be done with a "no-regret" strategy. Just do the right thing. Think about the communications architecture that overlays the power system. We use 155 different communications protocols in this industry. Start thinking about inter-operability, one device talking to another device, and imagine the nightmare we are facing!

Investment in upgrading is necessary. Instead of spending about $20 million a year, the current expenditure on the transmission and distribution system, it needs to be doubled. This may mean a three to five percent increase in everybody's electric bill, but it's situational. Obviously, the specifics depend on location.

Allen Crabtree

Bold suggestions from Clark. Any responses?

Marc Mahoney

We're not revolutionary at this point, not that we don't need to be, but there are a number of new technologies available and they are slowly being installed. The electric grid is growing more complex yet society is becoming ever-more dependent on it. This situation is only going to become more threatening. One of the areas most in need of revolutionizing is that of protection systems (back to the security issue). There's heavy-duty technology out there which isn't all that expensive. Let's face it, the industry has an aging-asset problem—aging poles and transformers. The system still has a lot of electric mechanical relays that need to be replaced. Why not replace them with the latest and greatest technology? It would provide a wealth of information to the engineers who are planning the system.

Many utilities have been moving in this direction over the last five or ten years and do have programmatic approaches to relay replacement.

Allen Crabtree

Ken, how would your businesses take to an approach like that if they were asked to help with some of these updates?

Ken Pokalski

What we're seeing in the US is a disinvestment in our infrastructure. Infrastructure is not just important to individuals, but to our over-all economic success, whether it is public water treatment, electric power, or transportation. There's a broader public need to think about. How do we allocate our collective resources? Increasingly, resources are being developed to transfer the costs of capital and infrastructure improvements. From a business perspective, that's going to make it increasingly difficult to be competitive in the US. The economy relies on a good infrastructure in order to be successful and cost effective.

We recognize that infrastructure improvements are going to be expensive. We accept that the industrial-commercial sector must bear a share of that burden. We often see a heavier burden on the commercial-industrial sector rather than residential, because the reasoning goes, they can afford it. Well, that's not necessarily the case any more. As we all know, more and more of our economic activities are off-shore.

From the public side, somebody has to make infrastructure improvements a higher priority for government. We need greater emphasis on maintaining existing infrastructure.

Marc Mahoney
I'd like to tie together some of the comments made by Clark and Ken. It's true we need to invest more in the infrastructure, but I don't think it's necessarily true that it will cost more. It's going to cost more in terms of transmission rates, but not necessarily in the overall costs paid. When you go home at the end of the week, look at your electric bill. (In New England and New York, they're itemized.) One of the smallest charges on the bill is transmission—maybe eight or ten percent of your bill. Certainly that will go up as we invest more in transmission infrastructure. However, if we reduce the risk of loss of supply, and the economic dislocations caused when certain high-priority lines go out, there is a return on that investment. Certainly Path 15 would qualify. If the power goes out unexpectedly because of a relay problem, or a tower collapses, or a transformer fails, and it's out for 24 hours, the customers are paying the bill. As we learned from Path 15, it could be $100 million a day or more. There is a payback that could offset many times over the investment in transmission—if it's done correctly.

Allen Crabtree
We heard Peter comment in his keynote address about problems that lead to deferment of maintenance—necessary maintenance.

Clark Gellings
We asked 400 business and industry leaders across the nation whether or not they'd be willing to pay three to five percent more on their electric bill if they could be assured of an infrastructure that was resilient. Interestingly, about half of them said yes. The other half said no, because they have an uneasy feeling, one of distrust. They reasoned that if they allowed an increase, the money would probably be spent on something else. I think this demonstrates that not only are there problems with the infrastructure, but also there are problems with public perception.

Allen Crabtree
Let me toss this out to you, Marc. Put your regulatory hat on. Let's weave together what we've been talking about—environmental permitting, economic incentives or disincentives, reliability questions, and some of the technical concerns. Are our comments here today appropriate? Or are they missing the mark? Are there answers?

Marc Mahoney
I think everybody is concerned about knee-jerk reactions to blackouts. Let me be a little provocative. It is tough for me to say this, having directed vegetation management operations for the last 15 years, but unfortunately it's true that our current vegetation management programs have failed the electric power industry.

Again, I have to bring up the word "proactive." We need to act, not react. Regulators, scientists, and vegetation management professionals need to work together to establish regulations that focus on the "what," as opposed to the "how," in order to improve what vegetation management can offer the industry.

It's a panacea to think that "one size fits all," or that prescriptive regulations are the answer. For example, establishing a four-year treatment cycle nationwide as a standard is not going to work. I believe regulation should be performance-based, and I believe FERC is the entity that should promulgate those regulations.

Allen Crabtree
Any comments on Marc's observations? Is he absolutely correct? Peter says yes. Clark?

Clark Gellings
I liked what you said about being proactive, Marc, because one thing that's missing in this industry is leadership. Very few are willing to stand up and point the way.

Booker Holton
Peter and I agree that part of the answer is in mandatory controls, but there should be more. Once upon a time we talked about the ISO 14000-14001 series, which was thought of as a sort of "Good Housekeeping Seal of Approval" certification. It never got there. Would it be possible to have every company use, as part of its normal operations, a process that recognizes environmental stewardship without standards? Are there internal standards developed as part of the corporate core?

Years ago I worked on developing strategies for the concept of environmental asset management. This concept challenges us to take stock of our environmental resources and make them assets. Then, we must manage those assets. If we, as an industry, adopt these concepts, that would be the ideal.

Allen Crabtree
Well, I think being proactive is certainly not only desirable, it's very, very important. Self-regulation may be the goal, but don't we need someone to play traffic cop? Who's going to mediate between the elm savers and the fish savers in Berleville? They both have a legitimate point of view. You're going to turn them lose with chain saws at 50 paces?

Peter Berle
I don't have the definitive answer, but I'd like to go back for a moment to the ISO 14000 concept. To me, the most exciting thing about ISO 14000 was being on a path of constant improvement. You don't meet the standard and then go home. Inherent in the ISO 14000 certification is the notion that you're constantly trying to improve.

I was dealing with an architect, when I was head of Audubon, to build the greatest office building in the City of New York. We were talking about code, and the architect said, "Remember, if you build according to code, you're building the worst possible building that the law will allow you to put up. It's the minimum standard." I think, with respect to a lot of regulatory activity, the assumption is "I will meet it and then I can go home."

When I was fighting with Jack Welsh about PCBs in the Hudson, we had quite different views at one point. I pointed out to him that the rules didn't change. They had a responsibility, not only as far as the rules were concerned, but as corporate citizens in this world. He said, "Listen, Commissioner, you tell me what the standard is and I'll meet it." And that was fair enough, but the fact was, that wasn't necessarily going to create a healthy environment.

We need the standards and we need the culture that ISO 14000 was trying to encourage. We need to encourage responsibility to improve. Too frequently we assume that if we change the regulation it will fix the problem, which, of course, is not usually the case.

Ken Pokalski

The vast majority of ISO 14000 participants with whom I've spoken are in the program because they're required to be, either because they're a vendor to the US military, or vendor to a company that requires it as a condition of their contract. What I often hear from large and small companies is that there's no other incentive to join.

We must be more successful in changing the culture and more successful in creating benefits for those who go beyond the bare minimum.

Here's an example. I met several times last year with delegates from the Netherlands who have a very different environmental regulatory approach than we do here in the US. The basic approach is that they bring in representatives from a specific industrial sector and basically negotiate what can be done at these facilities to protect the environment. It's almost the ultimate approach. The air emission standard that applies to the chemical industry isn't necessarily one that's being applied to the primary metals industry.

We're never going to get there in the US due to the vast body of command and control-type regulations that we have. Reasonable people work out compliance flexibility. It means a net gain to the environment and a net gain to the company, which is something relatively difficult to do with the environmental regime we have in place in the US.

Booker Holton

You mentioned before that the EPA has a pilot program to get some kind of regulatory relief as an incentive. I believe there could be other incentives too. It could be similar to the insurance industry, for example, which has more relaxed rates or allows exaggerated depreciation schedules. Criteria could include such items as whether the company has an Emergency Management System or if it subscribes to the principles and the philosophy of ISO 14000. I think there's creativity out there and that is what is needed in order to establish that incentive.

Ken Pokalski

Absolutely. In the environmental literature, there's a lot written about sustainability. The EPA has had any number of initiatives over the past two decades, a sort of "flavor of the month" approach. One thing the regulated community needs is to be able to plan on sustainable incentives. The regulated community needs to know that these initiatives are going to be around for a long time and not disappear with the next administration.

Allen Crabtree

Let me turn to the audience for their thoughts before we conclude our panel.

Kevin McLoughlin

I mentioned earlier that Article 7 of the Public Service Law in New York has been around for 34 years. The Public Service Commission, on a number of occasions, has tried to revise and update those regulations. One of the things they proposed was aggressive public outreach. They went so far as to say that the utility, instead of coming forward with an application that would show the line, the route, the need, and the environmental compatibility, should come in with an application that says that we need a line, but we don't know exactly where it should go. We should let the public process start that early. In other words, we should have the concept that we need a line rather than a proposal and have the public come in and help us route it. What do you think about that type of situation? Is it like holding an election with no candidates?

Marc Mahoney

If it's Article 7, we're probably the ones making the application. We've been thinking about taking a more collaborative approach. We're just not sure exactly how quickly we can get there, partly because of our internal cultural perhaps. Our planners find a problem and the next step is to look at numerous options to solve the problem. Will there be underground or multiple routes or FACTS devices? We look at everything. It's not an exaggeration to say that some of our planning studies can generate 20 or 30 options. Our approach is to look at those options and calculate the cost and benefits for each one. Then, we go to the public and say, "Listen, we don't have it exactly figured out."

We are accustomed to a boss saying, "Don't come to me with problems; come to me with solutions." I'd hate to go to the public and say, "We don't know what we're doing." We are most comfortable coming to the collaborative process with options. We expect other options will evolve from there. Thirty options may increase to 40 or 50, but at least there has been a place to start.

We do agree, though, that it should be much more collaborative.

Booker Holton

In 1992, the Western Utility Group tried to resurrect some maps with transmission-line corridors. Unfortunately they were crudely done on a large scale—pre-GIS but the idea was sound. Let's have a public process. The real problem is drawing the line on a map, because there are implications for property rights and eminent domain. A line is drawn, but it's meant to be an interactive process with a lot of public involvement. If everyone comes out and says, "Oh, no, you're not going to put it there," you shift it.

Let's develop a master plan for corridors, particularly the state corridors. The memorandum of understanding between the federal government and the Western Governors' Association tries to facilitate that process. Nevertheless, there are difficulties. There are obvious security problems. How much do you tell the public? What maps should you use? Who should be reviewing and taking a look at those things?

Frank Williams

I am hearing a lot of discussion about eminent domain, pipelines, and downtown development. What are your thoughts on eminent domain changes? What kind of controversy do you see coming?

Peter Berle

I've had some experience both with representing landholders who don't want to be appropriated and with exercising eminent domain. When I was a commissioner, a lot of the facilities for the 1980 Olympics were built in Adirondack Park, on lands under my jurisdiction. I indeed exercised the power to take land for the cross-country ski runs.

There's no more emotional issue than losing your house, losing your land, taking your grandfather's stone wall. We live in a society in which private property, with respect to land, is a core value. A lot of societies don't work that way. It's always intrigued me that this right to private property is not part of the culture of native peoples.

In addition, the property rights movement has been growing. It is a political force, which in my judgment, has been destructive.

My sense is that in order to do things for the public good, one must have the power. However, if it's going to work, it must be used only as the last resort (and that's how a lot of the state authorities operate). There was a time when rights-of-way people could say, "If we can't get it otherwise, we'll take it," but that type of situation engenders the kind of hatred that produces lines of people in front of bulldozers. But without eminent domain, it's hard to put a complex scheme together. You need the ability to ensure the route at some point.

The growing strength of the property rights movement and the continual challenges to eminent domain in the courts lead me to believe that both the ability to regulate land use and to take land through public process may become more and more limited. What that means is that one has to be more responsible about using eminent domain—using it in a fair way, recognizing that there are people who will be dissatisfied, and coping with that.

Jeff Kemper

We noted that ensuring adequate transmission is a very complex issue. I wonder whether there is a point at which this complexity becomes so great that the alternative is something other than the movement of electrons over long distances, perhaps a more centralized approach. Are we reaching that point? Will we ever reach that point?

Clark Gellings

Current projections for distributed resources show that they will satisfy an increasing share of new generation. Nationally, distributed resources have the potential to account for about 20 percent of new generation. When resources are distributed, they can create a more resilient power delivery system, and may obviate the need for some new or upgraded transmission lines. However, when we look at the huge increases in consumption that we are expecting to see in the years ahead, it's going to be very difficult to justify economically a system that has a great number of distributed resources ("a great number" meaning enough so that no new transmission lines are required). The bulk power delivery system is here to stay. The extent to which it will be improved, upgraded, and strengthened is up for debate.

Ken Pokalski

The distributed approach encounters some of the same issues as the merchant power lines. To what extent are the owners-operators running the unit for their own exclusive benefit? What are their obligations to the system at large? It brings up regulatory questions about staying connected to the grid for backup power. Do you have to share? What's the cost? What cost should be borne by an individual company on behalf of overall system reliability? The issue of cost allocation has been an impediment to large-scale distributed generation in New York.

Allen Crabtree

Thank you. Before we conclude our session, I'd like to ask the panel for any final comments they would like to offer.

Peter Berle

We talked about questions to which there are no easy answers. I would like to emphasize that we have a common need, but different ideas about what we're prepared to sacrifice to meet that need. The challenge is to construct a suitable framework in which these decisions can be made. And, we need to recognize that it will require continuous revision. My own sense is that there is more room for FERC, not only to set the ground rules, but to encourage some sort of order.

There are certain basic human values that prevail. Our task in solving problems is to come back to those and achieve success. Thank you.

Booker Holton

I will end on a philosophical note. I agree that we, as a democratic society, have to believe in the public trust: the right to clean air, to clean water, to live in an environment that is safe and secure. These are inalienable rights that we should support. When making planning decisions, it should be remembered that everyone has a right to question what we do. Our job is to respond with the most environmentally-friendly point of view that we can.

Marc Mahoney

I'd like to leave the group with a charge in the form of an aspiration about stewardship. We need to recognize that we provide an essential service to our customers. We operate, maintain, and develop our networks in order to minimize the risk of supply interruptions. We should manage our transmission and distribution networks with a long-term view towards reliability, and the investment in infrastructure, operation, and planning necessary to provide a robust network. We should strive to operate an injury-free workplace that protects the safety of the public and to make every effort to minimize our impact on the environment. That is our collective charge.

Clark Gellings

I would like to offer a quote taken from an article in the July 2001 issue of "Wired" magazine which discusses the challenges facing the electric energy industry: "The challenge before the electric industry is formidable. The current power infrastructure is as incompatible with the future as horse trails were to automobiles." It goes on to acknowledge, "With an aggressive public-private collaborative effort, we can solve this problem." I agree. Thank you.

Ken Pokalski

I would like to make two comments that relate to the fact that before a solution can be found, the parties must be prepared to find a solution. First, let me say that the shorthand definition of my profession is "lobbyist." My goal is to negotiate solutions. I've been at it for 20 years. I remain optimistic, although it seems harder at both the national and state level to reach successful compromises.

A couple of years ago, after a particularly discouraging legislative session, I developed a kind of simple-minded optimism. I believe that there's not an issue we talked about that can't be resolved if people come to the table with reasonable expectations and reasonable demands. Anyone involved in the public debate who doesn't come to the table with reasonable expectations and demands should be sent out of the room. They are not going to help reach a conclusion.

So many times when we find ourselves reaching for the regulations, we are actually trying to resolve a situation that arose from a lack of planning. One of the issues being addressed at this conference is how to put transmission corridors in heavily urbanized areas. Integrating longer-term planning is going to eliminate some of the obstacles. At times, regulation is the only tool available, but that doesn't mean that it is necessarily the right tool for the job. Long-term planning and long-term perspective are the keys for meeting future energy needs and environmental goals.

Allen Crabtree

Thank you to the panel for sharing your thoughts and observations. There are many interrelated, complex, varying, and dynamic factors at play. We have not identified one specific solution or even a group of solutions today. We well know that there are no simple, definitive answers to situations with this level of complexity. But, we hope that we have been able to peel away some of the layers obscuring the clarity of our vision for the future.

Larry Abrahamson

Thank you panel, and an especially warm thanks to Allen.

BIOGRAPHICAL SKETCHES

Allen F. Crabtree

Allen Crabtree is a principal with Navigant Consulting, Inc., an international management consulting firm that provides services to the power and water industries, among others. Allen Crabtree was formerly Senior Vice President of the Environmental Division of Resource Management, Inc. until that firm was acquired by Navigant Consulting in 1997. He has been with RMI/Navigant since 1991. Prior to 1991, Allen Crabtree was a private consultant with an environmental consulting firm in New Hampshire, Executive Director of the New Hampshire Fish and Game Department, Assistant Division Chief of the Geological Survey Division. He also held several management positions with the Environmental Enforcement Division, Michigan Department of Natural Resources, the Michigan Public Service Commission, and worked at the Federal Power Commission in Washington, DC.

Kenneth J. Pokalski

Ken Pokalski is the Director of Environmental and Regulatory Programs for the Business Council of the State of New York. He is responsible for legislative and regulatory advocacy on environmental and economic development issues and is the staff director of The Business Council's Manufacturing Council. He also oversees The Business Council's review of the state's rulemaking activities and is responsible for issues relating to the State Administrative Procedures Act.

Mr. Pokalski provides a liaison with the Department of Environmental Conservation, the Empire State Development Corporation, and the Governor's Office of Regulatory Reform.

He has been with The Business Council since 1982. He is a graduate of the State University of New York, Albany, receiving an M.P.A. at the Graduate School of Public Affairs in 1983. In 1980, Mr. Pokalski received a B.A. in Political Science at State University of New York at Brockport.

Clark W. Gellings

Clark Gellings is Vice President of Power Delivery and Markets at the Electric Power Research Institute (EPRI) in Palo Alto, California. He joined EPRI in 1982 as a program manager and subsequently served as a senior program manager, director, Vice President of Customer Systems, Vice President of Client Relations, CEO of EPRICSG, Vice President of Retail Energy, and Vice President of Technology Initiatives. Prior to joining EPRI, Mr. Gellings spent 14 years with Public Service Electric and Gas Company.

Mr. Gellings is a member of the Board of Directors of EPRIsolutions, PRIMEN, Inc., the California Institute for Energy Efficiency, and EPRI PEAC. He is Chairman of the Board of Global Energy Partners, LLC.

Mr. Gellings has received distinguished awards from a number of organizations, including The Illuminating Engineering Society, the Association of Energy Services Professionals, and the South African Institute of Electrical Engineers. He is a 2003 recipient of CIGRE's (International Council on Large Electric Systems) Attwood Award for notable contributions.

Mr. Gellings is a registered professional engineer, a Fellow in the Institute of Electrical and Electronics Engineers (IEEE), a Fellow in the Illuminating Engineering Society (IES), a vice president of the US National Committee of CIGRE. He is active in a number of other organizations, as well. He holds a Bachelor of Science in Electrical engineering from Newark College of Engineering, a Master of Management Science from the Stevens Institute of Technology, and a Master of Science in Mechanical Engineering from the New Jersey Institute of Technology.

Marc Mahoney

Marc Mahoney is Vice President of Transmission Network Asset Management for National Grid. Through his leadership on environmental management, in 2001 National Grid became the first transmission system in the United States to achieve ISO 14001 registration. From 1989 to 2000, he served in a variety of senior line management positions with the Eastern Utilities Associates, including Vice President of Field Operations. Mr. Mahoney currently serves on the board of directors of the Audubon Society of Rhode Island and on the executive board of the American Red Cross, Rhode Island Chapter. He is a member of IEEE, and past chairman of the New Hampshire division. Mr. Mahoney holds a B.S.E.E. from Worcester Polytechnic and an M.B.A. from Northeastern University.

Booker Holton

Booker Holton is an applied ecologist and environmental planner with over 20 years of experience in environmental assessment and resource management on behalf of utility, commercial, industrial, and government organizations. Dr. Holton evaluates the environmental impacts associated with developing new energy facilities, transmission lines, pipelines, roadways, water resource development, wastewater treatment facilities, land use, and land management. He has particular expertise in areas of terrestrial and systems ecology, environmental planning and regulatory permitting. Dr. Holton has participated in over 200 biological assessment and habitat management studies, environmental assessments, and environmental planning projects.

He is a principal with TOVA Applied Science & Technology located in Orinda, CA. Previously he held positions as vice president at Resource Management International, Inc. (RMI) in Sacramento, CA, president of the Western Ecological Services Company, Inc. in Novato, CA, and vice president with EIP Associates in Sacramento, CA.

Dr. Holton has a Ph.D. in Ecology from University of California, Davis, an M.S. in Botany from University of Connecticut, Storrs, and a B.S. in Biology and Earth Science from Central Connecticut State University, New Britain.

Part II
Vegetation Management

Vegetation Management Best Practices for Reliability and Ecosystem Management

Richard A. Johnstone

Utility rights-of-way corridors provide a mean to convey energy to run the nation's economy and are vital links for national security. Utilities must control tall growing vegetation to allow ready access for emergency repairs or routine maintenance and to prevent contact with high voltage conductors. Many utilities control vegetation by routine cutting with mechanized mowers or chainsaws. This tends to encourage re-sprouting growth by the more aggressive plant species, many of which are non-native exotic plants. Integrated Vegetation Management (IVM) is a method of controlling vegetation by identifying problem species and a threshold level of when control is necessary, and then choosing from an assortment of methods to eliminate the problem plants and encourage the desirable species. A trained arborist should first inspect the site and schedule the appropriate management tool in a prescriptive fashion. Use of a GIS mapping program can merge land use and environmental information from government sources with the utility's facility locations and access points. Controlling incompatible trees and invasive plants allows more growing space for low growing grasses, forbs and shrubs. This permits more selective and lower disturbance rates as natural competition between plant species, and the activity of wildlife, result in cultural and biological controls. The result is a fairly stable meadow or shrub-scrub community that provides excellent wildlife food and cover, streamside riparian buffers and rare plant habitats. This has enabled some utilities to establish Memoranda of Understanding (MOU) with government land management agencies, and to assist in the control of invasive plants and wildlife habitat improvements.

Keywords: Integrated Vegetation Management (IVM), utilities, GIS, habitat, MOU, ROW

INTRODUCTION

Utility rights-of-way (ROW) can be seen in every town, city and open space across the country. They have been with us so long that most people don't "see" them anymore, much less think about them. Electricity that the power poles and wires provide is taken for granted, and the need to control vegetation within these corridors is not given much thought. The primary reason for vegetation maintenance is safe, reliable and accessible electric service, but if managed properly ROWs can also serve other vital functions. Utility ROWs can provide wildlife corridors, rare or endangered species habitat, fire breaks, and improved national security. The management of ROWs by establishing a threshold of need and using cultural and biological controls to augment the human activities of cutting and herbicide applications is termed Integrated Vegetation Management (IVM).

Cutting vs. herbicides

The majority of ROWs are maintained with mechanical cutters that periodically mow down the vegetation. In the past, when ROW were initially cleared with bulldozers or root-raked and replanted in grasses, mowing was relatively effective in preventing trees from dominating the sites. New environmental laws for sediment control restrict initial ROW clearing to top cutting of vegetation with chainsaws or harvesting equipment. Cutting the tops of trees does not change the complexion of the plant community because it does not change the specie composition and increases density. The total number of undesirable stems appears to increase

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because of multiple stem sprouting from stumps and roots (Abrahamson et al., 1995). Couple this with energy deregulation price freezes of the 1990's that forced some utilities to cut costs by delaying vegetation maintenance; trees now dominate previously maintained ROW.

The effectiveness of mowing is short-lived and with brush growing into trees too large for mowers, the next tool available to utility arborists is the chainsaw. But some property owners and public agency officials object to the cutting down of trees to reclaim the utility corridor. The alternative is tree pruning, which at best is only capable of temporarily preventing tree-conductor contact and routinely exposes workers to the safety hazards of sharp saws, and the environment to oil and gas contamination. If pruning is not performed at regular intervals, or accelerated after wet growing seasons, the conductors are at risk of arcing electricity into the trees with a resulting power outage and possible forest fire. The 2003 blackouts affecting 50 million people in the northeastern United States and Canada, and 57 million people in Italy were both caused by tree-conductor conflicts.

Trees are not compatible with safe and reliable transmission of electricity and should never be allowed to coexist within high-voltage utility corridors. Stephen Covey advises in his book *The 7 Habits of Highly Effective People* that one should "begin with the end in mind." If ready access and reliable service are the goals, then one should not maintain potential problem trees but instead change the composition of the plant community from species that can interfere with these goals, to species that are compatible with the goals.

Tree removal may be necessary if saplings have grown into trees, and a new hydraulically operated piece of equipment called the Marshall Tree Saw can minimize sprouting by cutting below the root collars of trees. But after the ROW corridor is reclaimed the problem plants should be prevented from again dominating the site. This need can only be accomplished if the below-ground portions of plants, their root systems, are rendered inoperative. This requires the use of herbicides; chemicals that can kill the root systems of plants and prevent further growth. Selective application of these products can effectively control interfering tree species while permitting the growth of low-growing plants that are compatible with the operation of the ROW.

Although herbicides are readily available, a Michigan State study (Sulak and Kielbaso, 2000) of utility vegetation maintenance found that the vast majority of utilities still maintain vegetation with mechanical cutting. When asked why more of them did not use herbicides, utility management perceived that cutting was more cost effective and readily acceptable to the public.

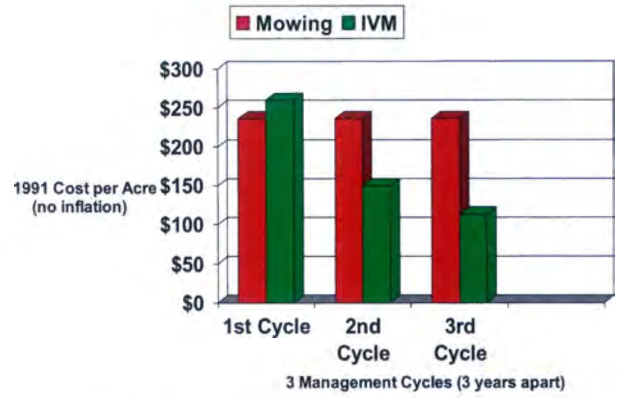

Fig. 1. ROW vegetation management cost per acre.

If only one maintenance cycle is observed, the perception of economics can be justified. Maintenance mowing can appear economical because its cost is very similar to that of an initial herbicide treatment without the need for much planning or training. Utilities need simply to entertain the lowest bid for easily achieved cutting specifications. But where cutting must be 100% replicated on the next maintenance cycle with inflationary increases in cost, herbicides prove to be a more judicious choice. The majority of the incompatible trees are eliminated with the initial application, and if subsequent treatments are selectively applied, one can lower the cost as compatible low-growing plants are encouraged. The graph below (Fig. 1) is a case study of ROW Vegetation Management Cost per Acre at Delmarva Power for 3 cycles of mowing versus spraying without adjusting for inflation (Wildlife Habitat Enhancement Council, 1992). The average cost for mowing in 1991 is compared against the average cost for herbicide treatment of ROW in varying stages of control; 1st herbicide treatment, 2nd herbicide treatment, 3rd herbicide treatment. The decreasing cost of successive treatments demonstrates the effectiveness of IVM at reducing stem counts of the target undesirable trees. Figure 2 shows the annual cost savings over 25 years on 1,000 linear miles of Delmarva Power transmission ROW using actual annual costs of IVM (mowing to selective spraying) compared to 1980 actual mowing costs adjusted for inflation. The cumulative savings is about 7.5 million dollars!

Environmental stability

Research over the past 50 years by Drs. Bramble and Byrnes, as well as Yarnell, Abrahamson, Nowak and others, has demonstrated that low growing plants become relatively stable communities and continue to work for the utility by passively restricting tree growth. Plants compete for sunlight, nutrients and growing space, and inhibit other plants by their dense root mats and rhizomes (Byrnes et al., 1995) and may release allelopathic chemicals (Putnam, Tang, 1986). Animals that utilize this habitat also restrict tree encroachment through seed and seedling consumption (Bramble et al., 1992).

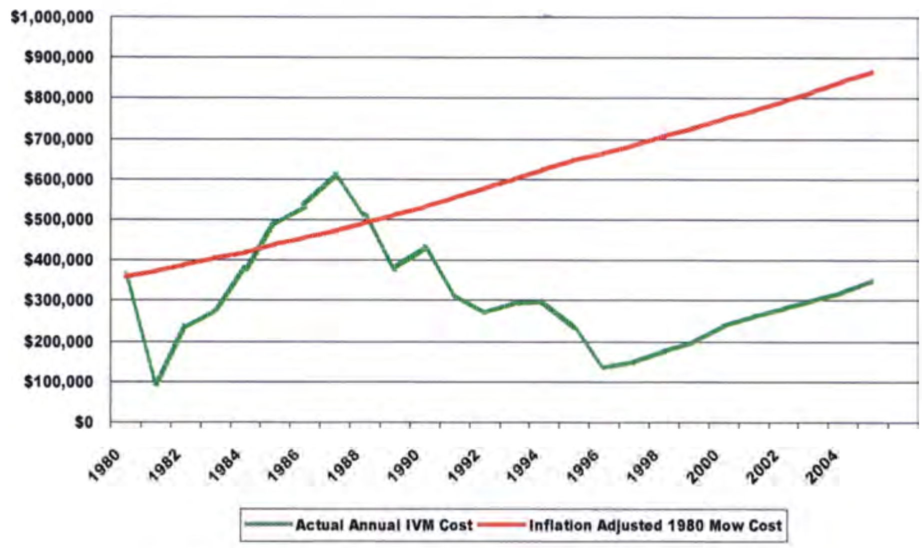

Fig. 2. 25-year vegetation management treatment cost comparison.

IVM can provide much-needed habitat for a wide diversity of animals and early successional plant species. By adjusting the herbicide mix and application technique, a 3-tiered ROW can be established; grasses in the center for access with increasing heights of shrubs and then small trees toward the ROW edge. Creating a shrub layer along a forested ROW provides a feathered edge that helps disperse songbird nests and possibly discourage predation by cowbirds (Gates and Evans, 1996). Since many of the animals and plants that benefit from this regimen are now threatened or endangered because of habitat loss, proper use of IVM can provide the last refuges of their habitat. The Maryland Natural Heritage Program has identified over 50 rare plant species in 22 power line sites on Maryland's Eastern Shore and 7 of these species occur nowhere else in the state but on power line ROWs (Maryland Natural Heritage Program, 1992).

IVM can improve on environmental stewardship in several ways. First, IVM can improve the health of the environment by removing exotic invasive plants. Invasive plants can form monocultures that displace native plants and offer little food or habitat for wildlife. They are a major cause of habitat degradation. Second, IVM lowers input of manmade chemicals into the environment since herbicide volume decreases over time with each selective application. Reducing dependence on mowers and chainsaws will reduce the negative impacts associated with these treatments; their inherent spillage of oil, gasoline and hydraulic fluid, and routine tire rutting of soil on slopes, in wetlands and riparian areas. This decreases risk to humans and the environment, the goal of a voluntary cooperative agreement with the United States Environmental Protection Agency, the Pesticide Environmental Stewardship Program (PESP).

Many state and federal natural resource agencies have the same misconception as utility administrators; herbicide use is risky while hand or mechanical cutting has a benign effect on the environment. The multiple benefits of an IVM approach have not been disseminated to those in a position to decide its use. So if a utility approaches the need for vegetation management only on its own terms; i.e. reliability and access, and does not take the time to research the management objectives of the forest/refuge and the benefits of IVM, it is no surprise that only cutting is permitted.

"Seek first to understand, then to be understood" is another of Stephen Covey's 7 Habits, which if practiced would lead more parties to the use of IVM. If utilities understood the management objectives of a forest/refuge and each respective manager was knowledgeable on the methods of IVM, then the best management practices could be used to find synergy and satisfy the multiple objectives of all.

Case study

Conectiv Power Delivery (Atlantic City Electric) was negotiating for permits to construct a new 230 kV transmission line on an existing corridor in the state of New Jersey. Conectiv's System Forester was able to demonstrate to the U.S. Fish and Wildlife Service that IVM techniques could be adjusted to meet the diverse habitat needs of two different endangered species, the bog turtle (*Clemmis muhlenbergii*) and swamp pink (*Helonias bullata*). The bog turtle requires open wetland meadow habitat and it has been extirpated in many areas of the state due to habitat loss from development, invasion by exotic plants and natural plant succession to trees. The utility's management plan for potential bog turtle habitat was adjusted to target not just trees but also the invasive reed grass *Phragmites australis* for removal and herbicide treatment. The necessary open wetland meadow was restored, thus providing an ecosystem for the possible future habitation by bog turtles.

The swamp pink is an orchid that grows in the shade of a forested wetland habitat in contrast to the open meadow. Conectiv chose to selectively herbicide treat only tall growing trees and allow native viburnum (*Viburnum dentatum*) and laurel (*Kalmia latifolia*) shrub species to proliferate and provide the necessary shaded conditions. A sparse population of Phragmites australis also present in the wetland was not herbicide treated since the shade provided by the shrub species would naturally restrict its spread, taking advantage of an IVM cultural control. The Service Administrator granted the construction permit for the new line and also agreed to endorse the judicious use of herbicides on ROW within the Pinelands National Reserve, where ROW herbicide use has not been permitted for 30 years.

Memoranda of understanding

Cooperative partnerships were negotiated under Memoranda of Understanding (MOU) between Conectiv and the four states within its service territory; Delaware, Maryland, Virginia and New Jersey, as well as the Northeast Region of the U.S. Fish and Wildlife Service. The agreements recognize the management objectives of the agencies and serve to achieve those objectives along with the utility objectives in a synergistic fashion. ROW now serve as fire breaks for the state Forest Fire Services and are recognized as wildlife corridors by state and federal Fish and Wildlife Services. Since all parties are educated on the mutual management objectives, general permits using best management practices are being negotiated instead of pursuing individual permits for each capital or maintenance project. This "win-win" proactive approach saves the agencies and the utility time and money in meeting respective missions of service to the public.

Research by CN Utility Consulting, LLC (2004) has identified state highway departments as the agencies most likely to restrict the operations of electric utility arborists. This is quite surprising when the vegetation management needs of both entities are so similar. Hurricanes, snow storms and ice storms have demonstrated that falling trees and branches do not discriminate between blocking of roadways and knocking down utility poles and wires. Transportation departments and utilities should be working cooperatively to remove hazard trees that threaten both services to the public. They also are missing an opportunity to lower their respective vegetation management costs by not coordinating mowing and herbicide applications. Compare their management objectives: Utilities want grasses and herbs along the center of their ROW for access and reliability – highways want the same plants for sight distance near the road shoulders; utilities allow growth of low shrubs gradually increasing in size to trees along the ROW edge – highways allow low shrubs with gradual increasing in size to trees along their corridor edge. Cooperation would provide synergy, lowering costs and improving service to the public.

GIS benchmarking

Utility foresters often sound like Rodney Dangerfield claiming; "I get no respect!" While it's true some construction and engineering departments refer to the forestry department as the "tree cutters," foresters help perpetuate this nomenclature by not being proactive. Foresters are frequently guilty of maintaining a "cycle trimming" approach instead of a "reliability management" approach, with claims of inadequate budgets without being able to define what an adequate budget looks like. You cannot manage what you don't know!

In the 21st century, arborists and utility foresters have the ability to know what needs to be managed by using a geographic information system (GIS) as a management tool. GIS is a tool that can accurately record what is present on a ROW along with corresponding tree interference to predict what it will cost to perform various management procedures. Progressive utilities plan work with trained arborists using GIS programmed laptop computers. One such approach is the ROWKeeper developed by Davey Resource Group on Conectiv's system. Arborists record linear or square feet of vegetation interference on GIS digital maps, negotiate with customers for continuous improved tree reliability, and print work order maps for use by the vegetation contractors. Tree pruning, removal, mowing or herbicide treatment is prescriptively issued on a circuit by circuit basis with a benchmarked cost for completion using the best management practice for that procedure. Work can be performed under an alliance agreement using negotiated rates for manpower and equipment, or issued under a unit price or lump sum contract. Under an alliance agreement, crews that can professionally complete the work below the benchmarked cost are awarded a bonus, while those circuits that exceed the benchmark may be penalized. The contractor has an incentive to continuously improve and lower long-term costs while vegetation reliability continues to improve through the use of IVM.

When a vegetation manager knows what vegetation problems exist and what it costs to manage, one can accurately request a budget to improve reliability of the circuits. If management responds that the dollars requested are not available, the manager can request guidance from the reliability engineer to pick which circuits not to address. This sharing of responsibility removes the tree related outage category from forestry and places it where it belongs – across all utility management. Vegetation management is a cost of doing business! IVM best management practices can effectively lower that cost.

Outreach

The IVM education needs of foresters, utility management, agency administrators and the general public are being answered in several ways. Edison Electric Institute Vegetation Management Task Force produced an electric ROW stewardship video/study guide and VMES, LLC contracted with Virginia Tech University to produce a 13-minute training video outlining the similarities between utility and highway ROW vegetation management. The Department of Interior National Training Center produced an IVM training video for use by federal wildlife refuge managers titled; *Managing Utility Right-of-Way for Wildlife Habitat*. This production demonstrates how utility corridors can enhance the goals of a wildlife refuge if managed properly. It was distributed in DVD format to all United States federal wildlife refuges in 2005 and shared with other federal agencies.

An MOU between the electric industry and federal land management agencies is being developed to recognize the importance of safe, reliable and accessible ROW for our nation's homeland security and wildfire control, and the benefits IVM provides for wildlife, endangered specie habitat and invasive weed control.

CONCLUSION AND RECOMMENDATION

Utility ROW encompass millions of acres of land in our country and, if managed properly, can ensure the public's vital energy supply, protect our nation's homeland security, assist in wildfire control, provide wildlife habitat, manage ecosystems conducive to rare and endangered species, and control noxious and invasive weeds. Past confrontational approaches between utilities and government agencies have resulted in major power interruptions, while invasive weeds continue to spread and ecosystems required by rare species dwindle. New promising efforts are underway to educate utility and agency land managers on the benefits of IVM in a synergistic approach and formal memoranda of understanding are being negotiated. With greater understanding and appreciation for respective management needs, all parties can better serve the public and our natural resources.

REFERENCES

Abrahamson, L.P., C.A. Nowak, P.M. Charlton, and P.G. Snyder. 1995. Cost effectiveness of herbicide and non-herbicide vegetation management methods for electric utility rights-of-way in the Northeast: state-of-the-art review. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, 27–43.

Bramble, W.C. and W.R. Byrnes. 1983. Thirty years of research on development of plant cover on an electric transmission right-of-way. Journal of Arboriculture, 9(3): 67–74.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnick. 1990. Resistance of Plant Cover Types to Tree Seedling Invasion on an Electric Transmission Right-of-Way. Journal of Arboriculture, 16(5): 130–135.

Bramble, W.C., W.R. Byrnes, R.J. Hutnick, and S.A. Liscinsky. 1991. Prediction of cover type on rights-of-way after maintenance treatments. Journal of Arboriculture, 17: 38–43.

Bramble, W.C., R.H. Yahner, W.R. Byrnes, and S.A. Licinsky. 1992. Small mammals in plant cover types on an electric transmission right-of-way. Journal of Arboriculture, 18(6): 316–321.

Byrnes, W.R., W.C. Bramble, R.J. Hutnik, and S.A. Liscinsky. 1995. Right-of-way site factors responsible for resistance of certain plant cover types to tree invasion. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, 76–80.

Canham, C.D., J.D. Hill, A.R. Berkowitz, and R.S. Ostfeld. 1995. Ecological perspectives on tree invasion in rights-of-way: quantifying variation among communities in resistance to tree invasion. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, 81–86.

CN Utility Consulting, LLC. 2004. Utility Vegetation Management Final Report. 131 pp.

Covey, S.R. 1989. The Seven Habits of Highly Effective People. 372 pp.

De Blois, S., J. Brisson, and A. Bouchard. 1995. Selecting Herbaceous Plant Covers to Control Tree Invasion in Rights-of-Way. Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, 103–110.

Environmental Protection Agency. 2005. Pesticide Environmental Stewardship Program: www.epa.gov/oppbppd1/PESP/.

Federal Energy Regulatory Commission. 2004. Utility Vegetation Management and Bulk Reliability Report. 22 pp.

Gates, J.E., and D.R. Evans. 1996. Powerline Corridors: Their Roles as Forest Interior Access Routes for Brown-headed Cowbirds, A Brood Parasite of Neotropical Migrants. Final Report. 41 pp.

Howland, R. 2001. Utility Deregulation: An Undergrowth of Opportunity. Tree Care Industry Volume X11, Number, 1: 54–58.

Johnstone, R.A. 1990. Vegetation Management: Mowing to Spraying. Journal of Arboriculture, 16(7): 186–189.

Johnstone, R.A., M.R. Haggie, and H.A. Allen Jr. 1995. Tree, Shrub, and Herb Succession and Five Years of Management Following the Establishment of a New Electric Transmission Right-of-Way through a Mixed Woodland, 73–81.

Johnstone, R.A. 1995. Vegetation Management with Environmental Stewardship. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, 456–459.

Maryland Natural Heritage Program. 1992. Rare Species in Powerline Rights-of-Way: A Proposal for a Long-Term Monitoring Study on Maryland's Eastern Shore. 11 pp.

Nickerson, N.H. 1992. Impacts of vegetation management techniques on wetlands in utility rights-of-way in Massachusetts. Journal of Arboriculture, 18(2): 102–106.

Putnam, A.R. and C.-S. Tang. 1986. The Science of Allelopathy. Wiley Interscience. 317 pp.

Sulak, J. A and J.J. Kielbaso. 2000. Vegetation Management Along Transmission Utility Lines In The United States and Canada. Journal of Arboriculture, 26(4): 198–204.

Vegetation Management Task Force (VMTF). 1996. Environmental Stewardship Strategy for Electric Utility Rights-of-Way. Edison Electric Institute. Washington, DC. 9 pp.

Wildlife Habitat Enhancement Council. 1992. The Economic Benefits of Wildlife Habitat Enhancement on Corporate Lands. Wildlife Habitat Enhancement Council. Silver Spring, MD. 6 pp.

Witt, J.L. Associates, LLC. 2004. Pepco Holdings, Inc. (PHI) Hurricane Isabel Response Assessment. 173 pp.

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Richard A. Johnstone is a Registered Professional Forester and Owner of VMES, LLC (Vegetation Management with Environmental Stewardship) consulting and President of IVM Partners, Inc. (Integrated Vegetation Management Partners) a 501-C-3 non-profit corporation. He has 28 years experience as a utility system forester applying IVM practices cooperatively with public agencies and conservation organizations along sensitive habitats of the Mid-Atlantic United States. He develops vegetation management programs and provides training to industry, university, military and agency personnel and produced with Virginia Tech the video *Integrated Vegetation Management: Principles and Practices for Rights-of-Way.* He co-authored the *Environmental Stewardship Strategy for Electric Utility Rights-of-Way* for the Edison Electric Institute Vegetation Management Task Force, and was part of their negotiating team to develop memoranda of understanding between the electric industry and federal agencies. He served as an expert advisor for the *Joint United States – Canada Power System Outage Task Force Final Blackout Report.* He provided professional expertise for the vegetation management training DVD produced by the Department of Interior's National Training Center; *Managing Utility Rights-of-Way for Wildlife Habitat* distributed to federal wildlife refuge managers in 2005. Cooperative vegetation management partnerships for invasive weed, wildlife habitat and ecosystem management are provided under cost-sharing grants with IVM Partners, Inc. He served as President of the Utility Arborist Association and received their 2003 Education Award for adding to the knowledge and practices of Utility Arboriculture. He earned his BS degree in Forest Resources Management from West Virginia University in 1976.

Development of an Integrated Resource Management Strategy for Transmission Right-of-Way Corridors for Successful Implementation of Integrated Vegetation Management in California

Nelsen R. Money

Pacific Gas and Electric manages 18,000 miles of transmission lines in California within five general bioregions that extend from the coastal areas to the Sierra Nevada/Cascades. The development of an integrated resource management (IRM) strategy through the use of integrated vegetation management (IVM) techniques, have reduced environmental and social conflicts. Vegetation managers are actively promoting the benefits of IRM to ecological, cultural, and economic resources to obtain approvals for their vegetation management of transmission rights-of-way. Specific techniques are presented that have been developed to allow utilities to use integrated vegetation management methods to provide safe and reliable energy while maintaining positive property owner relationships. Using IVM to accomplish IRM successfully integrates a wide range of environmental issues as well property owner concerns. A matrix of IVM techniques is described to show how desired vegetation types can be established and maintained.

Keywords: Integrated resource management (IRM), integrated vegetation management (IVM), wire zone-border zone, ROW

INTRODUCTION

Utility vegetation management in California is a challenge with the diversity of landowners and interests. The complexity of managing the corridors has increased from the time when they were initially created. The majority of transmission corridors were established decades ago when the lands were large parcels consisting of timberlands, cattle grazing ranches, agricultural and wildlands. Transmission corridors moved the bulk electricity from hydro generation sites in the Sierras to the growing cities to the west. The political and social environment was very positive toward the availability of electricity to a growing state and economy. Land management goals and environmental concerns have changed over the last 50 years.

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Most landowners accepted the establishment of transmission corridors and the last fifty years of routine maintenance. Large mechanical mowers or brush rakes usually conducted initial clearing and the future maintenance. Some of the vegetation control in the early 60 s was also with the use of aerial applications of herbicides.

Forest management on the State and federal lands during the construction and first fifty years of maintenance of corridors was generally even-aged harvesting. Many of the corridors were cleared through young regenerated forests that had been recently harvested. Forest management encouraged ground disturbance and the use of fire. This type of regeneration strategy resulted in many early successional species of vegetation and wildlife along the corridors.

Rural development was minimal and the management of corridors was rarely in conflict with the local communities. Ranchers surrounding rural developments used fire as a tool to reduce fuels and improve grazing. Many of the large parcels were managed under an open range policy. This management also en-

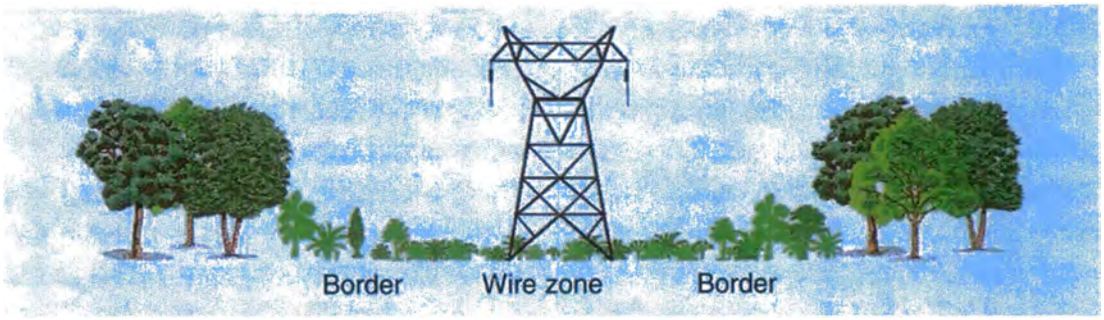

Fig. 1. Vegetation management Wire zone/Boarder zone.

couraged and maintained an early successional vegetation types around rural developments.

Large agricultural farms were the dominant land use in most of the central valley of California. Most agricultural crops were compatible with transmission corridors. Winter wheat, rice, and many fruit orchards were managed within the transmission corridors. Many agricultural lands within the central valley have now been developed into urban and rural cities. Some agricultural areas have switched from lower growing crops to taller growing nut trees such as walnuts and almonds.

Within the last twenty years, conflicts between environmental and local regulations have become more frequent and forest management shifted to limited harvest activities and a change to more mature forest types. Federal and State forests management is moving toward selective harvesting that is designed to maintain mature or over mature forest stands. Wildlife species are shifting from early successional species to more climax species. Restrictions on the use of fire due to air quality and changes in grazing use have shifted rangeland to dense stands of mature brush and trees. Vegetation types in the surrounding areas have also changed from early successional species to more climax species. The use of fire is very limited now and many sites have seen a reduction in early successional species. Many of the threatened and endangered species utilities find in their corridors are early successional species.

Currently, utilities within California provide a management plan to the California Independent System Operator, CAISO, on their maintenance. PG&E's right-of-way projects focus on long-term management goals including providing safety for the public and employees and minimizing tree-related outages while providing access for inspection and maintenance of facilities as well as for the timely restoration of service during emergency conditions. Right-of-way projects are managed using the Wire zone/Boarder zone method, Figure 1. The Wire Zone includes the corridor area under the transmission wire plus 10 feet on both sides and is managed for low-growing vegetation. The Border Zone extends from ten feet outside of the wire to the edge of the ROW and is managed for taller vegetation and is considered a transition zone. Managing vegetation within corridors with Wire zone/Boarder zone concept also helps lessen the impact of catastrophic fires on facilities.

A vegetation project manager working on a typical transmission corridor today can anticipate many different challenges. Identifying the landowners, mailing notification letters, investigating the past and present land use, and reviewing environmental regulations require significant time to plan. Project managers are using an Integrated Resource Management (IRM) approach to recognize goals of landowners and agencies before the project starts and incorporate them into their vegetation management strategy.

INTEGRATED RESOURCE MANAGEMENT (IRM)

Integrated resource management is a decision making process to develop long-term sustainable benefits for the landowners and the utility. IRM requires a planning process that identifies all compatible resource uses between landowner and the utility. What makes the integrated resource management approach so successful is that the vegetation manager investigates the resource management goals of each landowner to determine how his activities can also help in managing for the landowners' interests as well as the utilities interests.

The utility vegetation project managers will look for compatible resource uses such as wildlife, cattle grazing, endangered species, noxious weeds, recreational, and fuel hazard reduction.

Wildlife diversity is very important to many landowners and is mandated on many state and federal lands. Project managers should look for opportunities to develop vegetation types that encourage wildlife diversity. When adjacent forests are managed for mature and climax species, it is important to develop lists of early successional wildlife species that would be found in the transmission corridors. An understanding of early successional species and their importance in species diversity can help gain approval from agencies and landowners.

Grazing land is important to ranchers and can be a very compatible use with the utilities vegetation management of corridors. Ranchers recognize the need for vegetation management and generally prefer vegetation maintenance that requires fewer site visits from the utility. Development of stable low growing grass and herbaceous plant communities that have grazing benefits and only require cycles of every five to six years of selective herbicide applications by the utility are very acceptable by ranchers. Ranchers can also be very interested in the fuel breaks that are provided by vegetation that meets the Wire zone/Boarder zone concept.

Recreational resource can also be a compatible use. Corridors within the Sierras have mountain biking and horseback riding potential during the summer and are also used for cross-country skiing and snow mobiling in the winter. Development of stable low growing vegetation can help reduce the impact of each of these recreational uses. Utilities can offer removal replacement programs to provide low growing trees and other compatible brush species for golf courses that have tall growing trees species in place. Hunting opportunities can also be increased with development of vegetation types that encourage use by deer, quail, pheasant, and wild turkeys.

Endangered species are frequently found within corridors. These early successional species can be identified and their early successional habitat increased. Vegetation project managers need to have the knowledge of successional changes in vegetation to advise agencies promoting no activities around endangered species, which can lead to the loss of the species due to other competing vegetation. Botanists with a good understanding of the morphology of the plant can help the vegetation project manger develop integrated vegetation management techniques to maintain and enhance the habitat.

Noxious-exotic weed management is a concern with many federal, state and county managed lands. Exotic species can be identified by the vegetation project managers and plans developed to control the species and encourage the native species to reclaim the corridor. Agencies managing endangered species that are threatened by exotic weeds are very interested in utilities working with them to control these exotics.

Fuel hazard reduction is a very important joint benefit to the landowner and utility. Many rural communities have recognized the benefit of transmission corridors managed for low growing species. Vegetation project managers can reduce the fuels from the past and develop low growing species with several integrated vegetation management techniques. Communities benefit from the fuel breaks developed adjacent to the wire zone and the utilities have vegetation within the wire zone that will not generate flame heights that would destroy the facilities.

Integrated resource management can identify the compatible uses for the vegetation project manager and the use of integrated vegetation management techniques can help establish the vegetation and maintain long-term stability.

INTEGRATED VEGETATION MANAGEMENT (IVM)

IVM is the art of managing the course and rate of plant succession to create desirable plant communities that promote the achievement of vegetation management objectives by integrating science-based knowledge of plant ecology with a variety of complementary methods that are ecosystem-based, economical, and socially acceptable (Adapted from Wagner 1994, and McLoughlin 1997). The following complementary methods are used by utility vegetation managers to control and manage vegetation in transmission corridors: manual, mechanical, cultural, biological and chemical. Each method is considered a tool in the vegetation managers tool bag and provide them the ability to create vegetation types that are desirable and sustainable for long periods of time for the utility and the landowner.

Manual vegetation control is the use of chainsaws, string trimmers, machetes, etc to cut individual tall growing trees and brush species. It can be an effective tool when there are not large numbers of stems. Vegetation managers often use this method in rocky or steep terrain or in cultural sites where mechanical equipment is not an option. Manual methods can also be used in the transition to stable herbaceous plant communities when non-resprouting species, i.e. conifers are invading a recently mowed corridor.

Mechanical vegetation control is effective when slopes and soils permit their use. On corridors with mature dense brush and trees, mechanical mowing can provide the site scarification that promotes rapid early successional revegetation of a corridor. The chips and masticated debris provide erosion control. Mechanical can also involve the use of brush rakes on sites where soil erosion is not an issue. Mechanical brush raking is often used on ranches with cultural methods of reseeding with grazing mixes to increase cattle grazing opportunities. Removal of the roots of resprouting species can also help reduce the herbicide application in future cycle treatments.

Cultural methods can vary from the use of reseeding for establishing specific vegetation types such as pastures to the establishment of agricultural crops compatible in the corridor such as vineyards, Christmas tree plantations or other low growing crops. Establishing golf courses or parks with tree restrictions within the wire zone can also be acceptable cultural method.

Biological methods include the use of cattle and goats in the maintenance of stable vegetation in transmission corridors. After utilities establish the low growing vegetation, ranchers will provide the future maintenance with sustainable grazing that promotes a stable vegetation community. Goats with the use of portable electric fencing can be contained in areas within the transmission corridor as a method to reduce certain vegetation. Goats can also damage desirable vegetation and may not graze on certain undesirable vegetation. The establishment of stable low growing species, i.e. grasses and forbs, is also a form of biological control that reduces the re-invasion of the corridor by tree species. Some plant species also have the ability to inhibit the growth or invasion of other species which is referred to as allelopathy.

Chemical control methods can be selective or non-selective. Most vegetation managers are using selective methods to target only trees and brush that are not desired in the corridor. In the past, pounds of active ingredient were required and now it is usually only ounces per acre. New chemistry, i.e. Imazapyr (Stalker) and Clopyralid (Transline), have significantly reduced the amount of herbicide require per acre to maintain stable plant communities.

The chemical application methods of basal stem, hack and squirt, closed injection and spot foliar have helped to reduce the amount of herbicides per acre. Control of exotic species, which are adjacent to endangered species, can be very effective with selective herbicides that are applied with selective application techniques. Imazapyr(Stalker) has been used in spot applications to control wood tree species such as oaks and conifers.

Tree growth regulators (TGRs) are a chemical control method that is being used on transmission corridors where undesirable fast and tall growing species cannot be removed. TGRs such as Profile 2 are used to reduce the growth per year by reducing the cell elongation. Some trees controlled by TGRs can see a reduction in annual growth of 50% and trees can skip annual pruning for two to three years. Species such as redwood, liquid amber, eucalyptus, elm, and oak are good candidates for tree growth regulators. Selective application methods used with tree growth regulators are basal drench and soil injection. Where trees are required for shade requirements or local regulations, tree growth regulators can reduce the pruning required, reduce safety hazards for tree contractors on busy roads and reduce the wood waste.

SUMMARY

The future will include increasing environmental compliance regulations, more local regulations and increasing public issues. Utility Vegetation managers can plan the maintenance of corridors with an IRM strategy which coordinates IVM techniques to help provide a stable vegetation complex that is important to the utility and meets one or more goals of the land owners. Recognizing the mutually beneficial goals that can be incorporated into the utilities long-term management of the corridor can improve the utilities customer satisfaction with landowners, agencies and communities.

REFERENCES

DowAgro Sciences Company, www.dowagro.com/ivm/utility/bio/brambles.htm CD "Bramble, Byrnes and Biodiversity. A Half Century of Helping You Get the Word Out."

State University of New York-College of Environmental Science and Forestry, www.esf.edu.

International Society of Arboriculture, www.isa-arbor.com.

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Stable Plant Communities in the Pacific Northwest

J.C.B. Nesmith, J.P. Shatford, and D.E. Hibbs

The application of stable low-growing plant communities as a tool in right-of-way (ROW) management is new in the Pacific Northwest. The development and use of this approach has been primarily in northeastern North America. We initiated a multi-year program to assess the application of this method to rights-of-way in the highly productive western hemlock zone of the Pacific Northwest. Working in the western Cascade Mountains of Oregon and Washington, we found a mix of deciduous and coniferous trees growing in established electric utility rights-of-way that had been treated 3 to 4 years earlier. To identify types of species that were effective in limiting regeneration of trees, we examined gap closure processes in rights-of-way where trees and tall-growing shrubs had been removed. We also examined the ability of some common low-growing shrub species to form dense thickets of vegetation. Gaps were most quickly closed by species capable of rapid horizontal spread through vegetative reproduction. Several of the common clonal shrubs found on the ROWs were also capable of forming dense thickets of vegetation. Thus, while there are necessarily differences at the species level between the western moist coniferous zone and the eastern deciduous zone, the importance of vegetative reproduction holds.

Keywords: Stable, low-growing, right-of-way, vegetative reproduction, resistance

INTRODUCTION

The Bonneville Power Administration (BPA) operates 15,000 miles of electrical transmission lines running through seven states in the Pacific Northwest. Much of the system runs through mountainous countryside including 1,400 miles of rights-of-way (ROW) that cross lands administered by the US Forest Service and the Bureau of Land Management. Some of the most productive temperate forests in the world reside west of the Cascade Mountains in Washington and Oregon. The region is characterized by diverse and lush vegetation with steep topography and a wide range of habitats.

Vegetation management has been vital to BPA since its inception in 1937. The management approach of choice has varied considerably over the decades, however. Initially, hand cutting was common, followed by a dependence on aerial spraying and herbicide use with the advent of herbicides in the '50's. A moratorium on herbicide use on federal forest lands in the '80's motivated change towards mechanical treatments. A serious incident in August 1996 caused by several vegetation related power failures resulted in blackouts across ten western states (Bonneville Power Administration, 2000). This led to more aggressive and deliberate vegetation management practices. Today, a combination of techniques is used including hand cutting, low volume basal herbicide, mowing and brushing, and grass seeding. Treatment cycles in the region range from 3–6 years on productive forest ROWs. The high cost of these ROW management programs has spurred an increased interest in the promotion of stable, low-growing plant communities as an alternative management approach.

There is a long history of research investigating the use of stable, low-growing plant communities as a management tool on rights-of-way (Bramble and Byrnes, 1983; Niering and Godwin, 1974; Mercier et al., 2001). Many benefits to this management approach have been documented and include reduced management cost (Niering, 1958; Finch and Shupe, 1997), increased habitat quality for wildlife (Yahner, 2004; Bramble and Byrnes, 1982), and a greater aesthetic appeal and social value (Bramble et al., 1992). Most of

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this research, however, has been conducted in the temperate deciduous forests of the eastern United States. An important question for Pacific Northwest ROW managers is whether the creation and maintenance of stable, low-growing plant communities can be an equally effective management tool in their region.

There are some fundamental differences in resource availability and species composition between the Douglas-fir (*Pseudotsuga menziesii*) dominated forests of the Pacific Northwest and the temperate deciduous forests of the Northeast. The western foothills of the Cascades in Oregon and Washington, where our study sites are located, are characterized by coniferous forest with high stand productivity and biomass accumulation (Franklin and Dyrness, 1973). High annual precipitation with dry summers, mild winters, and periodic fires (Agee, 1988) are the main influences on vegetation in this region. In contrast, forests of the Northeast are dominated by deciduous forest, with a rich flora and regular summer precipitation, but lower biomass accumulation. In 1999 we initiated a project in collaboration with BPA and Western Environmental Consultants, Inc. to investigate the use of stable, low-growing plant communities as a management tool in the Pacific Northwest. We were particularly interested in the dynamics of canopy gaps left by treatments. Which species filled in the space once target species were removed? Which species of low growing plants (shrubs or forbs) were both common and able to achieve abundant cover within gaps? To the best of our knowledge, this is the first long-term study investigating stable, low-growing plant communities on ROW in this region.

METHODS

Three lengths of either 230 kV or 500 kV power-line were selected from the western foothills of the Cascade Mountains in Oregon and Washington (Fig. 1). The sites were selected to be within the western hemlock zone (Franklin and Dyrness, 1973) and hence represent only a small portion of the environmental variation related to climate and elevation that occur in the region.

Each site was surrounded by forest dominated by Douglas-fir, the early to mid-successional dominant in the western hemlock zone (Franklin and Dyrness, 1973). The Brownsville, Skamania, and Tacoma sites have been in use by the electric utility since 1965, 1938, and 1972, respectively. The vegetation on these areas had not been treated for at least three years prior to the start of the study. The past management history on the sites varied, but since 1984, BPA treatments on ROWs have been primarily manual and mechanical cutting of target individuals with limited herbicide use.

The sites range in elevation from 100 m (330 ft.) to 450 m (1475 ft.) and average between 154 cm and 221 cm of precipitation per year (12–23 cm during

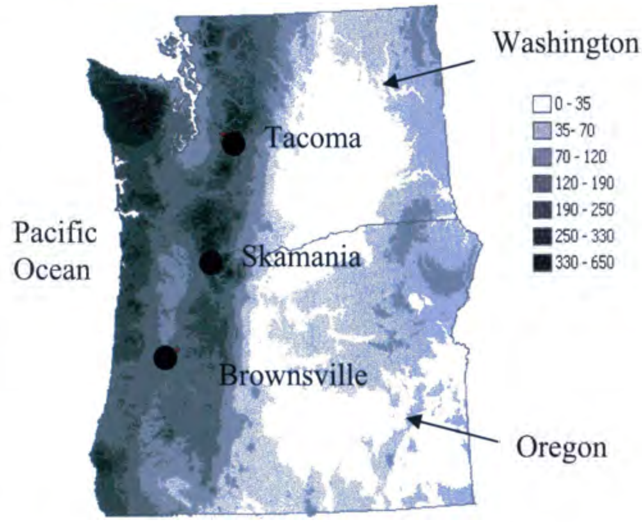

Fig. 1. Location of the sites in Oregon and Washington. Legend indicates average annual precipitation in cm (from data described in Thornton et al., 1997).

June–August). The Brownsville site is characterized by rolling hills with a silty clay loam. Skamania is characterized by shallow soils and dimpled terrain, forming wet depressions on some areas of the site. The soils are a stony clay loam. The soil at Tacoma ranged from deep to shallow sandy loam and is formed from glacial outwash. As at Skamania, rocky outcrops are scattered across the site.

Each site is approximately five hectares (12.5 acres) in size, though the length and width of each area varies. A manual cut and two different directed herbicide treatments were applied to each site during July of 2000. The aerial extent of a treatment block was approximately 1.25 ha. Each treatment was designed to reduce target species occurrence and abundance. Target species were defined prior to treatment application to include all species of woody trees and tall shrubs that were able to grow to a height over 3 m and two species of undesirable exotic shrubs: scotch broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus discolor*).

Vegetation was sampled in two different types of plots. Plots (2 × 2 m) located along permanent transects running from forest edge to forest edge were used to measure species composition and abundance on the ROWs. Grass cover and forb cover were recorded as plant types rather than as individual species. The plots were measured prior to treatment application in mid-April through mid-June in 2000 and then again in July–August, 2002. Between 470 and 511 plots were sampled at each site (Shatford et al., 2003). Gap plots (1 × 1 m) were installed post treatment in 2001, centered on treated target species, to measure the effect of the different vegetation control methods and species response following gap formation. A total of 121 gap plots were installed at the three sites (Nesmith, 2004). Average gap size created by the treatments was also calculated in 2001 and 2002 from measurements of the radial distance to live vegetation from the center of the gap plot in four directions.

RESULTS

A total of 35 woody plant species and 6 ferns were recorded within the study area. In 2000, prior to treatment application, the 2 × 2 m transect plots were dominated by tall shrubs, low-growing woody shrubs, and broom (Table 1). There were 3 coniferous and 3 deciduous tree species, 10 tall shrub, and 10 low shrub species. Grass and forbs were common but none appeared to dominate an area or form dense monocultures. The rights-of-way consisted of a complex patchwork of shrub thickets and coppice from previously cut hardwood trees and tall shrubs, especially vine maple (*Acer circinatum*), cherry (*Prunus emerginata*), hazel (*Corylus cornuta*), and big-leaf maple (*Acer macrophyllum*). Intermixed with these species were patches of low shrubs, ferns, and occasional small meadows of mixed forbs and grasses. Scotch broom, vine maple, and red alder (*Alnus rubra*) were the most common target species at Brownsville, Skamania and Tacoma sites, respectively. Snowberry (*Symphoricarpos albus* and *S. mollis*), salal (*Gaultheria shallon*), and thimbleberry (*Rubus parviflorus*) were the most abundant low growing shrubs. Species composition and species richness were similar among sites, but species abundance varied widely. Most of the low-growing species of shrubs and ferns are known to reproduce vegetatively, a growth strategy that may be favorable to the development of low-growing plant communities. Many of the tall-growing species, including vine maple, bitter cherry, and hazel, reproduce vegetatively by root or stump suckering.

Within two years of the treatments, gaps created by the removal of target species, measured in the 1 × 1 m gap plots, had been completely covered by new growth. Gap area in 2001 averaged 1.2 m^2 (±0.4 s.e.m.). By July, 2002, just 1 ½ growing seasons after treatment, gap area averaged <0.1 m^2 (± <0.1 s.e.m.). Some of the gaps were filled by desirable low growing vegetation, while others, especially those treated by the manual cut method, were filled by re-sprouting target species.

In general, most low-growing species that were initially present in the gaps or adjacent to them increased in cover following the removal of the target species, though the rate of increase among species was quite variable. Thimbleberry (*Rubus parviflorus*), trailing blackberry (*Rubus ursinus*), and bracken fern (*Pteridium aquilinum*) were widespread species that responded positively and rapidly to the removal of taller species (Fig. 2). The response of other species such as sword fern (*Polystichum munitum*) and snowberry was more variable (Fig. 2). Other species, such as red huckleberry (*Vaccinium parvifolium*) and salmonberry (*Rubus spectabilis*), which may be suitable candidates for low growing plant species in rights-of-way, did not occur frequently enough on our sites to be assessed.

Many of the shrub species were also capable of forming dense thickets within the high light environment provided by the right-of-way. We found that trailing blackberry and creeping snowberry (*Symphoricarpos mollis*) produced an average stem density of 113 stems/m^2 and 237 stems/m^2, respectively, in dense thickets at Brownsville. Several of the other common Pacific Northwest shrub species including salmonberry, salal, and thimbleberry are also capable of producing dense, persistent thickets of vegetation that can result in stable plant communities (Tappeiner et al., 1991; Huffman et al., 1994; Maxwell, 1990).

DISCUSSION

Shrub communities show potential for forming stable low-growing communities because of their ability to form dense thickets and fill gaps. The potential for vegetative reproduction and spread was a plant characteristic that was often associated with these functions. Shrubs may play an especially important role in contributing to the stability of low-growing plant communities in the Pacific Northwest where many of the common shrub species are capable of vegetative reproduction. Vegetative reproduction has also been shown to be an important species characteristic within stable plant communities in the Northeast (Meilleur et al., 1994). Therefore, while there are differences at the species level between the western coniferous zone and the eastern deciduous zone, the generality of the importance of vegetative reproduction holds. Long term studies in the Northeast have documented the dominance of both shrubs (e.g. *Viburnum spp.* and gray dogwood (*Cornus racemosa*)) and herbaceous growth (e.g. goldenrod (*Solidago spp.*) and hayscented fern (*Dennstaedtia punctilobula*)), which can form large contiguous patches that are resistant to tree

Table 1. Average cover (%) of different plant groups in 2000 prior to treatment application at the three sites. "+" indicates trace amount <0.05%

Site	Trees	Tall shrubs	Low shrubs	Ferns	Grasses	Forbs	Exotics	Total cover
Brownsville	6.3	6.7	19.6	5.9	2.3	1.1	12.6	54.5
Skamania	6.6	20.3	27.6	11.7	2.1	1.8	1.7	71.8
Tacoma	8.9	5.7	31.6	9	2.2	1.9	+	59.3

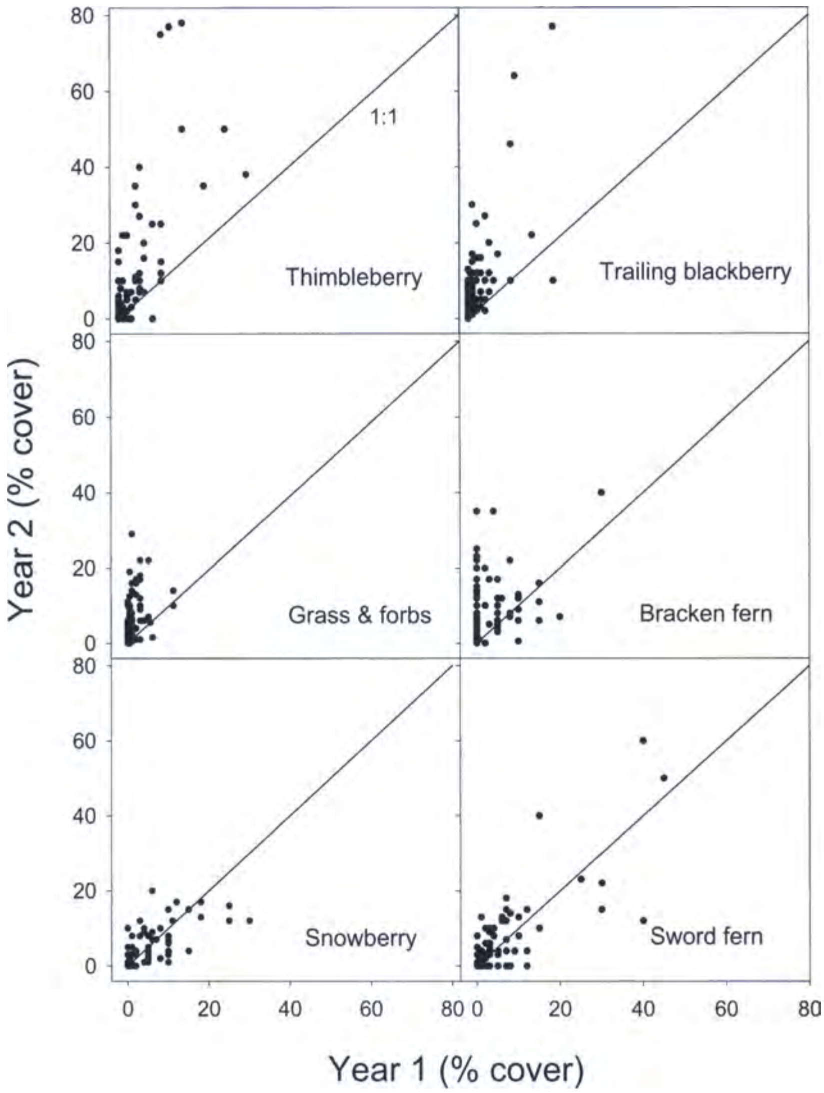

Fig. 2. Change in percent cover of selected low-growing species growing in gaps left by the removal of target species in rights-of-way. One to one line = no change with time, below line = a reduction, above line = an increase in % cover with time.

establishment (Bramble et al., 1990, Bramble et al., 1996). Only continued, well-targeted treatments and longer-term monitoring will determine if such single-species patches will develop on ROWs in our region and whether both woody and herbaceous species will prove capable of forming stable plant communities.

Along with the findings of our work, another important aspect of this project is that it has initiated a dialog between the scientific community and rights-of-way managers about how to better understand and manage stable, low-growing plant communities in the Pacific Northwest to reduce costs of ROW management. Though our results span a time period of only two years, and offer a very brief look at the role of stable, low-growing plant communities on ROWs, this research has led to a greater awareness of the potential importance of stable, low-growing plant communities as a management tool in the region, as well as an increased effort to disseminate this information to a broader audience. Our hope is that this project can provide an appropriate forum for addressing many of the ecological and management questions involved with ROW management and act as a conduit for the synthesis of information between researchers and managers.

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REFERENCES

Agee, J.K. 1988. Fire history of Douglas-fir forests in the Pacific Northwest. Pages 25–33 in Wildlife and vegetation of unmanaged Douglas-fir forests. United States Department of Agriculture Forest Service, General Technical Report PNW-285.

Bonneville Power Administration. 2000. Transmission System Vegetation Management Program DOE/EIS-0285 Final EIS. Portland OR.

Bramble, W.C. and W.R. Byrnes. 1982. Development of wildlife food and cover on an electric transmission right-of-way maintained by herbicides: a 30-year report. Purdue Agric. Exp. Sta., Research Bull. 974. 24 p.

Bramble, W.C. and W.R. Byrnes. 1983. Thirty years of research on development of plant cover on an electric transmission right-of-way. Journal of Arboriculture, 9: 67–74.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1990. Resistance of plant cover types to tree seedlings invasion on an electric transmission right-of-way. Journal of Arboriculture, 16: 130–135.

Bramble, W.C., R.H. Yahner, W.R. Byrnes, and S.A. Liscinsky. 1992. Small mammals in plant cover types on an electric transmission right-of-way. Journal of Arboriculture, 18: 316–321.

Bramble, W.C., W.R. Byrnes, R.J. Hutnick, and S.A. Liscinsky. 1996. Interference factors responsible for resistance of forb-grass cover types to tree invasion on an electric utility right-of-way. Journal of Arboriculture, 22: 99–105.

Finch, K.E. and S.D. Shupe. 1997. Nearly two decades of integrated vegetation management on electric transmission rights-of-ways in proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. J. R. Williams, J.W. Goodrich-Mahoney, J. R. Wisniewski and J. Wisniewski (eds.) New Orleans, Louisiana, USA Elsevier Science Ltd.

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. United States Department of Agriculture Forest Service, Pacific Northwest Forest and Range Experiment Station, Oregon. General Technical Report PNW-8.

Huffman, D.W., J.C. Tappeiner, and J.C. Zasada. 1994. Regeneration of salal (*Gaultheria shallon*) in the central Coast Range forests of Oregon. Canadian Journal of Botany, 72: 39–51.

Maxwell, B.D. 1990. The population dynamics and growth of salmonberry (*Rubis spectabilis*) and thimbleberry (*Rubus parviflorus*). Ph.D. Thesis, Oregon State University, Corvallis, OR.

Meilleur, A.,H. Veronneau, and A. Bouchard. 1994. Shrub communities as inhibitors of plant succession in southern Quebec. Environmental Management, 18: 907–921.

Mercier, C., J. Brison, and A. Bouchard. 2001. Demographic analysis of tree colonization in a 20-year-old right-of-way. Environmental Management, 28: 777–787.

Nesmith, J. 2004. Stable, low-growing plant communities in the western Cascade Mountains: Species processes and their implications for rights-of-way management. MS Thesis. Oregon State University, Corvallis, OR.

Niering, W.A. 1958. Principles of sound right-of-way vegetation management. Economic Botany, 12: 140–144.

Niering, W.A. and R.H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology, 55: 784–795.

Shatford, J., D. Hibbs, and L. Norris. 2003. Identifying plant communities resistant to conifer establishment along utility rights-of-way in Washington and Oregon. Journal of Arboriculture, 29: 173–177.

Tappeiner, J., J. Zasada, P. Ryan, and M. Newton. 1991. Salmonberry clonal and population structure: The basis for a persistent cover. Ecology, 72: 609–618.

Thornton, P.E., S.W. Running, and M.A. White. 1997. Generating surfaces of daily meteorology variables over large regions of complex terrain. Journal of Hydrology, 190: 214–251.

Yahner, R.H. 2004. Wildlife response to more than 50 years of vegetation maintenance on a Pennsylvania, U.S., Right-of-way. Journal of Arboriculture, 30: 123–126.

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Control of Woody Invasive Plants Using Mechanical and Chemical Treatments

Zachary E. Lowe, Harmon P. Weeks, Harvey A. Holt, and George R. Parker

Management of invasive and exotic plant species is a dilemma for rights-of-way and natural resource managers. Efficient, empirically developed control measures are needed for problematic species such as Amur honeysuckle (*Lonicera maackii*), autumn olive (*Elaeagnus umbellata*), multiflora rose (*Rosa multiflora*), and black cherry (*Prunus serotina*). Through proper application techniques, and the use of products designed specifically for woody plant control, 100% mortality of treated stems can be achieved using triclopyr, imazapyr, and basal oil in combination with basal or cut surface applications made in late winter or early spring before bud break.

Keywords: Amur honeysuckle, autumn olive, basal, black cherry, cut surface, exotic, herbicide control, imazapyr, invasives, mechanical control, mortality, multiflora rose, triclopyr

INTRODUCTION

Invasive plant management is a significant problem for rights-of-way and natural resource managers. Regardless of the ultimate management goal, invasive plant species are at the center of many vegetation management problems, and there is a lack of empirical work focused on detailed control measures for invasive woody species. Our research focuses specifically on the control of Amur honeysuckle, autumn olive, multiflora rose, and black cherry. Of these, black cherry is native but can be a vegetation management problem because of its fast growth and abundant seed production. The others, Amur honeysuckle, autumn olive, multiflora rose, are exotic invasive species that are particularly problematic in ecosystem management and utility rights-of-way throughout the central and eastern United States.

Invasive exotic plants typically out-compete and displace native species, thus reducing the long-term species richness and ecological integrity of the landscape (Bratton, 1982; Harty, 1986). Losses caused by exotic species invasions are well documented and pose a significant threat to natural systems worldwide (Hobbs and Humphries, 1995; Manchester and Bullock, 2000; Usher, 1986). Invasive plants grow and spread rapidly on sites with available resources. Therefore, rights-of-way are particularly prone to invasion because of resource availability, mostly light, and regular human disturbance. Once infested, rights-of-way can become conduits, spreading woody invasive species to other public and private lands (Hutchinson and Vankat, 1998). Thus, it is critical to develop efficient control measures for woody invasive species that can be incorporated into integrated vegetation and native ecosystem management.

Purpose

The ecology and life history attributes of invasive plants, such as prolific reproduction, competitive biology, and vigorous growth, make them a persistent ecological and vegetation management problem. The control and management of invasive plants, a key issue in current land use policy, often requires an integrated vegetation management approach.

Integrated vegetation management (IVM) focuses on the use of multiple resources and control methods to obtain a vegetation management objective. IVM regularly involves the use of herbicides at points through out the multiple processes leading to control (Hobbs and Humphries, 1995; Holt et al., 2002). Species-specific, empirical testing of the efficacy of herbicides improves our ability to understand and utilize

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herbicides properly in an IVM program. The problems associated with invasive plant establishment and IVM are a challenge for a wide variety of organizations responsible for land use management including natural areas, forestry, rangeland, and rights-of-way (Hobbs and Humphries, 1995).

In an effort to develop pragmatic invasive and vegetation management control strategies, Purdue University has developed a long-term research project focused on IVM techniques, invasive species control, and grassland restoration. The material outlined herein is a portion of this research project in which cut surface and basal application methods were tested for four woody plant species. Treatments involved several herbicide and mechanical combinations tested on three exotic and one native invasive plant species in order to determine efficiency of control. It is pragmatic to focus testing on invasive species because they are typically the most problematic when using an IVM approach. By testing against the invasive species, we examine control methods for problem plant species, and concurrently provide information that is useful to both natural resource and rights-of-way managers.

METHODS

Study area

The study site is on Midwestern properties owned by Purdue University located in west-central Indiana, United States. The region is dominated by row crop agriculture interspersed with forest patches, wetlands, and forested corridors along watercourses. Located at the ecological intersection of the Great Plains and Eastern Hardwood Forest, this area hosts a diversity of species and habitat types. This habitat diversity has allowed problematic invasive exotic species from both the western and eastern United States to establish in this region.

Experimental design

Study stems were selected randomly along linear transects that varied from 5 to 15 m wide depending on stem density, the more dense the stems the narrower the transect. Transects were in habitats that varied from old-field to early successional forest.

Once selected, root collar diameter measurements were made, and a metal identification tag was attached to each stem for all species. Amur honeysuckle and autumn olive stems were stratified into two size classes based on root collar diameter to avoid differences in treatment effect based on size differences within a species. Amur honeysuckle size classes ranged from 1.3 to 6.3 cm for the smaller stems and 6.4 to 15.9 cm for the larger stems. Autumn olive size classes ranged from 1.3 to 15.9 cm for the smaller stems and 16.0 to 31.8 cm for the larger stems.

Circular buffers were assigned to each study stem to reduce confounding that might occur if two treated stems had a shared or overlapping root system; 2 m diameter for the smaller stem size class and 4 m diameter for the larger stem class. Buffers provided spatial separation of test stems; no mechanical or chemical treatments occurred in the buffer areas.

Treatments were applied to all four species, as applicable, with treatments varying by combinations of herbicide mixture, herbicide concentration, and application method. Treatments were randomly assigned based on species and size class when applicable, each treatment was tested on 11 to 14 stems of each species. Standard application methods were used, with basal-application treatment extending from the root collar to a stem height of 45 cm ($\approx$18 inches) and cut-surface treatments being applied to the cambium in the cross-sectional area of the stump after the stem was removed between the root collar and stem height of 13 cm ($\approx$5 inches) (Holt et al., 2002).

The treatments included combinations of triclopyr (Garlon 4) and imazapyr (Stalker) and included an untreated control as well as a basal oil carrier only treatment (no herbicide). The basal oil carrier used was Ax-It from Townsend Chemical Division. Treatments were as follows:

1. Untreated control
2. Ax-It (basal oil, no herbicide)
3. Garlon 4 (20%) + Ax-It (80%)
4. Garlon 4 (20%) + Stalker (1%) + Ax-It (79%)
5. Garlon 4 (20%) + Stalker (3%) + Ax-It (77%)
6. Garlon 4 (15%) + Stalker (1%) + Ax-It (84%)
7. Garlon 4 (15%) + Stalker (3%) + Ax-It (82%)
8. Garlon 4 (10%) + Stalker (3%) + Ax-It (87%)

Individual stems received basal or cut surface treatments in late winter/early spring of 2003 (mid-March) before bud break. Stems were then monitored for two growing seasons (July, 2003 and August, 2004) to determine percent mortality for each species and treatment.

RESULTS

There is a high level of mortality (generally >90% for both basal and cut surface treatments) associated with treatments involving herbicide across all four species for both the first and second growing seasons. Shifts in mortality within treatments generally showed an increase in mortality from the first to the second growing season, or stayed constant at a high level of mortality. A reduction in mortality from the first to the second growing season, a trend shown in five of the forty multi-year treatments, accounts for 1 or 2 stems remaining alive within that specific treatment. Among the control and basal oil treatments, there was an increase in mortality from the first to the second growing season (Tables 1 and 2).

Table 1. Percent mortality of basal treatments applied pre-bud break an evaluated mid-growing season 2003 and 2004

Treatments*	Amur honeysuckle % mortality		Autumn olive % mortality		Multiflora rose % mortality	
	2003	2004	2003	2004	2003	2004
1) Untreated control	0	8	0	8	38	83
2) Ax-it (basal oil, no herbicide)	0	42	20	100	75	88
3) Garlon 4 (20%) + Ax-it (80%)	100	100	100	100	100	100
4) Garlon 4 (20%) + Stalker (1%) + Ax-it (79%)	100	91	83	91	100	83
5) Garlon 4 (20%) + Stalker (3%) + Ax-it (77%)	100	92	100	100	100	100
6) Garlon 4 (15%) + Stalker (1%) + Ax-it (84%)	91	100	92	100	86	83
7) Garlon 4 (15%) + Stalker (3%) + Ax-it (82%)	100	100	100	100	100	100
8) Garlon 4 (10%) + Stalker (3%) + Ax-it (87%)	100	91	100	100	100	100

*Each treatment is represented by 11–13 test stems, varying by species.

Table 2. Percent mortality of out-surface treatments applied pre-bud break and evaluating mid-growing season 2003 and 2004

Treatments*	Amur honeysuckle % mortality		Autumn olive % mortality		Black cherry % mortality
	2003	2004	2003	2004	2004
1) Untreated control	0	30	0	20	38
2) Ax-it (basal oil, no herbicide)	17	33	58	64	100
3) Garlon 4 (20%) + Ax-it (80%)	92	100	100	100	100
4) Garlon 4 (20%) + Stalker (1%) + Ax-it (79%)	100	100	100	100	100
5) Garlon 4 (20%) + Stalker (3%) + Ax-it (77%)	100	100	92	92	100
6) Garlon 4 (15%) + Stalker (1%) + Ax-it (84%)	100	100	100	100	100
7) Garlon 4 (15%) + Stalker (3%) + Ax-it (82%)	100	100	100	100	100
8) Garlon 4 (10%) + Stalker (3%) + Ax-it (87%)	100	100	100	100	100

*Each treatment is represented by 11–13 test stems, varying by species.

DISCUSSION

All herbicide treatments in this study have a high stem mortality rate. The high mortality rate is a product of combining proven application methods with herbicide combinations specifically designed for woody plant control. Previously, attempts to specifically control exotic invasive species have focused primarily on general use, non-selective herbicides (e.g., glyphosate) or mechanical removal alone for control (Luken and Mattimiro, 1991). These two methods have proven inadequate in providing effective control. The basal oil alone accounted for 33% to 100% of the mortality across all species, with a dramatic increase in mortality from the first to second growing season in all species and application types. Two herbicides, triclopyr (Garlon 4) and imazapyr (Stalker), were used in some treatments to create a mixture that had a broader species range of control. By using multiple herbicides and basal oil designed for woody plant control, we were able to reduce the amount of active ingredient (herbicide) used in some of our treatments, and maintain equal or better control than those treatments that used a higher amount of active ingredient.

The mortality within control treatments, except multiflora rose, was expected. Some incidental mortality is expected, such as that observed in Amur honeysuckle, autumn olive, and black cherry, and can be explained by plant competition and environmental stress (Luken and Mattimiro, 1991; Cousens, 1974). The mortality rates among control treatments were similar to those found by Luken and Mattimiro working with Amur honeysuckle in northern Kentucky, and were an acceptable representation of natural mortality.

Multiflora rose, however, had an unusually high mortality rate of 83% within the untreated controls. This is most likely a function of successional competition and a change in the local water table. Within the last two years, hydrologic restoration efforts have raised the local water table approximately 61 cm on the site. Observations of other multiflora rose plants on the research site reveal a general high level of mortality in areas affected by the increased water table.

CONCLUSION

Effective control of invasive species cannot be achieved through mechanical removal alone. A spray solution derived of a combination of herbicides and basal oil designed for the control of woody plants can be an effective control measure. The herbicide treatments showed high mortality rates for Amur honeysuckle, autumn olive, and black cherry when they are applied correctly and consistently in the late winter, or early spring, before bud break.

More work on the seasonal timing of application and on a wider variety of woody species is needed to help determine the scope of these treatment methods. Once thresholds are developed and understood, basal and cut-surface applications with these herbicide solutions could provide the possibility of year round application. The ability to effectively control woody species in the dormant season would provide a treatment option for seasonally inaccessible areas on rights-of-way and be useful in reducing non-target risk in the management of natural systems.

REFERENCES

Bratton, S. 1982. The effects of exotic plants and animals on nature preserves. Natural Areas Journal, 2(3): 3–13.

Cousens, J. 1974. An introduction to woodland ecology. Publisher: Bell and Bain Ltd., Edinburgh, United Kingdom. Chapter 2.

Harty, F. 1986. Exotics and their ecological ramifications. Natural Areas Journal, 6(4): 20–26.

Hobbs, J. and S. Humphries. 1995. An integrated approach to the ecology and management of plant invasion. Conservation Biology, 9(4): 761–770.

Holt, H.A., R.L. McKenzie, F. Whitford, L. Hipkins, J.M. Di Tomaso, R. Dickens, G. Blase, J. Orr, P. Northcut, and J. McKenzie. 2002. Model Certification Training Manual for Right-of-Way Pesticide Applicators. www2.agriculture.purdue.edu/pesp/rowmanual/.

Hutchinson, T. and J. Vankat. 1998. Landscape structure and spread of the exotic shrub *Lonicera maackii* (Amur honeysuckle) in southwestern Ohio forests. American Midland Naturalist, 139(2): 383–390.

Luken, J. and D. Mattimiro. 1991. Habitat-specific resilience of the invasive shrub Amur honeysuckle (*Lonicera maackii*) during repeated clipping. Ecological Applications, 1(1): 104–109.

Manchester, S. and J. Bullock. 2000. The impacts of non-native species on UK biodiversity and the effectiveness of control. Journal of Applied Ecology, 37(5): 845–864.

Usher, M. 1986. Invasibility and wildlife conservation: invasive species on nature reserves. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 314(1167): 695–709.

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Tree, Shrub, and Herb Succession and Five Years of Management Following the Establishment of a New Electric Transmission Right-of-Way through a Wooded Wetland

Michael R. Haggie, Richard A. Johnstone, and Hubert A. Allen, Jr.

A five-year study of vegetation succession was commenced following construction of a new electric transmission right-of-way (ROW) through a wooded wetland in Sussex County, Delaware, USA. In response to restrictions imposed by regulatory agencies that have declared only selective clearing of targeted incompatible tall-growing trees, with the retention of existing compatible low-growing trees and shrubs, is permitted for new ROW construction, this study investigates a comparison of clear and selective cutting methods. Prior to ROW establishment permanent quadrats were installed to evaluate the vegetation communities that followed clear-cut and select-cut tree removal. Integrated Vegetation Management (IVM) techniques were used as secondary interventions and compared against control sites. Baseline data were gathered and changes were documented for species numbers, diversity, stem count, and relative importance (RIV). The management of desirable ROW species and their relative wildlife use (WUI) are considered. Results show that IVM interventions stimulated vegetation succession from a mature wooded wetland to a low shrub/herbaceous community as successfully in the clear-cut as in the select-cut quadrats. Total numbers of species reflect that the loss of trees was later substituted by a twofold increase in the number of herbaceous species (RIV > 1). Shrub species = numbers remained relatively stable. The environmental effects of electric transmission ROW establishment and various vegetation management techniques upon plant species succession in wetlands are discussed.

Keywords: Relative importance value (RIV), wildlife use index (WUI), wetland, Delaware, clear-cut (CC), select-cut (SC), integrated vegetation management (IVM), selective treatment, ROW

INTRODUCTION

Several studies have shown vegetational changes in existing electric transmission rights-of-way (ROW) following a variety of treatments and management practices (e.g. Draxler et al., 1997; Finch and Shupe, 1997; Garant et al., 1997; Haggie et al., 1997). This study documents 5 years of vegetation succession following the establishment of a new electric transmission line through a mixed ash-magnolia-holly (*Fraxinus-Magnolia-Ilex*) wooded wetland with a pepperbush-azalea-winterberry-arrowwood (*Clethra-Rhododendron-Ilex-Viburnum*) understory. It contrasts the use of clear-cutting (CC) and select-cutting (SC) of trees for initial ROW clearing, with a subsequent integrated vegetation management (IVM) system or no treatment controls.

Since 1983 Delmarva Power, now Conectiv Power Delivery (CPD), has gradually implemented IVM in their transmission ROW vegetation management. CPD has evolved an IVM system which includes hand-cutting, mechanical control, herbicide treatment, and biological control (Hallmark, 1996). Herbicide use is coupled with a high degree of field crew education concerning the identification of desirable (D) and undesirable (U) tree and shrub species. These methods have not only produced a significant cost savings of $3 million to the company (Johnstone, 1997, pers. comm.),

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but have also created over 9,000 acres (3,642 ha) of wildlife habitat along 5,698 miles (9,171 km) of ROW in Maryland, Delaware, and Virginia (Wildlife Habitat Enhancement Council, 1992). Much of this habitat, ecologically termed old-field type, can have considerable value for certain wildlife species (Chasko and Gates, 1982; Delorey, 1992). In this study undesirable species include all tall trees that are capable of growing to a sufficient height so as to interfere with overhead utility wires. The height, and thus the species concerned, changes across the width of a ROW according to the arc described by the sway of the powerline catenary curve during wind and storm events (Byrnes et al., 1993; Arevalo-Camacho et al., 1997).

CPD, under whose auspices this research was initiated, has contracted with Chesapeake Wildlife Heritage to evaluate the effects of certain clearing methods, as well as herbicide and mechanical treatments, on plant succession along several sections of ROW in Maryland and Delaware.

GOALS AND OBJECTIVES

The research goal of this study was to document the vegetation changes that occurred following the establishment of a new ROW through a wooded wetland on the mid-Atlantic coastal plain. The purpose was to address questions by federal and state regulatory agencies during the ROW construction permit process concerning the environmental effects of clear-cutting (CC) versus selective-cutting (SC) of trees. From an economic standpoint clear-cutting, the mechanical removal of all above ground vegetation, is preferred over selective cutting for ROW preparation and establishment. From an environmental standpoint selective-cutting has been suggested by the permitting agencies as the preferred method, since it retains compatible low growing trees, shrubs, and herbaceous vegetation present at the time of initial ROW clearing.

Our research objective was to investigate whether a relatively stable shrub-swamp vegetation community could be established following a clear-cut, using judicious IVM interventions, that is as environmentally comparable as that empirically perceived in a selective-cut.

The utility company vegetation management objective is to cost-effectively foster relatively stable low-growing plant communities in order to minimize overhead transmission line interference and maintain access to facilities. This optimum situation can be most effectively achieved by using IVM with a gradual reduction of herbicides, ending with only periodic spot treatments (Bramble et al., 1987) and a reliance on natural allelopathy (Cain, 1997; Putnam and Teng, 1986; Horsley, 1977).

This study explores the merits of clear-cutting versus selective-cutting in new ROW construction, accompanied by IVM interventions.

STUDY AREA AND SITE HISTORY

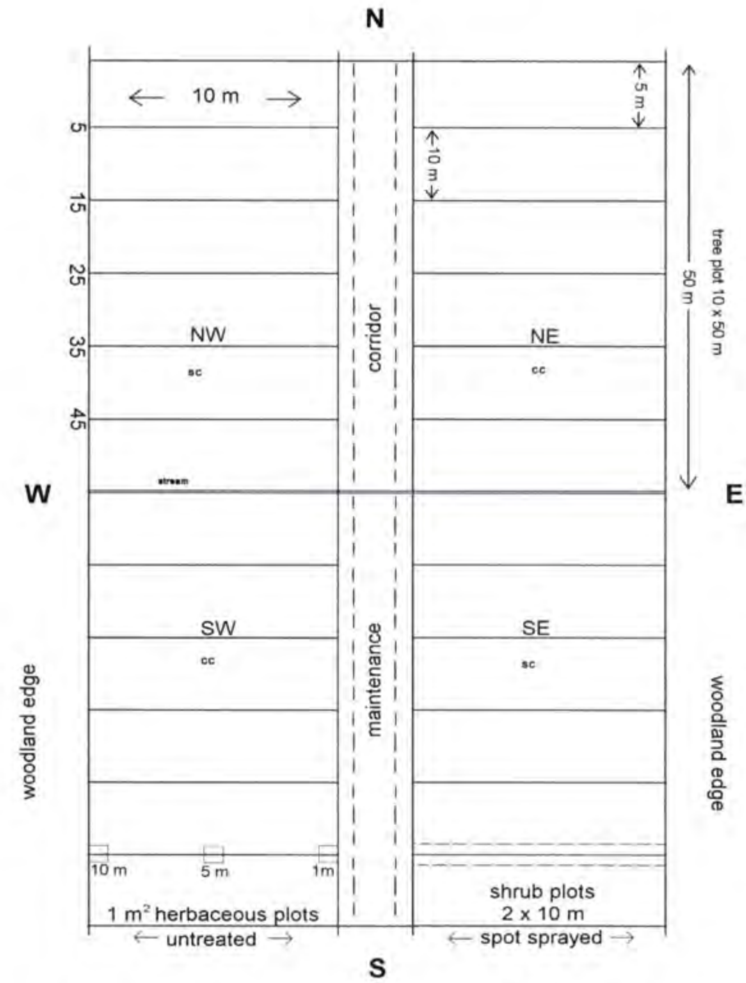
Located at Indian Mission off state Route 5 near Harbeson, Sussex County, Delaware, USA, the study area lies at coordinates 38°41′N and 75°14′W. New ROW construction commenced in the fall of 1992. This electric transmission line was initiated to facilitate power distribution from the generation point in Millsboro to Rehoboth Beach, Delaware (DP Circuit 13705 Indian River/Robinsonville). The 30 m wide ROW construction line runs north to south through upland along a 0.91 km wide tract of mixed maple-gum-holly (*Acer-Nyssa-Ilex*) woods, part of which was last logged in the 1950′s (estimation of age was based on tree size and ring count). The ROW is bisected west to east by Chapel Branch, a stream that drains into Rehoboth Bay via the Burton Prong of Herring Creek. The survey site was laid out north/south along this wetland section of the ROW, which intersects the stream branch at a right angle. The underlying soils consist of a silt loam that is part of the Johnston Series. These soils are very severely limited by excess water and are represented by very poorly drained soils on flood plains, being more or less constantly flooded or saturated year round. They are listed in the Soil Survey for Sussex County, Delaware as class 6, capability unit VIIw-1 and woodland class 2w (Ireland and Matthews, 1974).

MATERIALS AND METHODS

A linear transect survey method, suitable for following long-term vegetation succession, was used (Smith, 1966). A 30 m wide by 100 m long centrally located section of ROW, with a 10 m central access route, was selected as representative of the forested wetland vegetation. This block was subdivided into four 10 m × 50 m quadrants. Two tree quadrants were clear-cut (NE and SW) and two were select-cut (NW and SE). The east side of the ROW was selectively spot-sprayed (SS) in 1993 and 1997 with herbicide to control undesirable trees (Fig. 1). The west side remained untreated (UT) as the control until 1997. ROW herbicide treatment history is summarized in Table 1.

Baseline data of tree, shrub, and herbaceous species were taken prior to new ROW construction in the fall (September to October) of 1992, and subsequently each fall for 5 years from 1993 through 1997. Herbaceous data were also collected in the spring (May to June) from 1993 through 1997. A four letter code was assigned to each plant identified using the first two letters of the genus and species in the Latin name, e.g. *Lyonia mariana* = LYMA, or, if only identified to genus, LYSP.

Five 2 m × 10 m shrub plots, 10 m apart, were established north/south within each tree quadrant. Shrub survey lines were commenced 5 m from either end of each quadrant in order to reduce edge effect. One tree plot, 10 m × 50 m, was established within each quad-



NW quadrant = select cut (SC); cleared U-trees >5 cms DBH only and left shrubs; unsprayed control.
NE quadrant = clear cut (CC); removed all trees and shrubs; spot spray follow up.
SE quadrant = select cut (SC); cleared U-trees >5 cms DBH only and left shrubs; spot spray follow up.
SW quadrant = clear cut (CC); removed all trees and shrubs; unsprayed control.

Fig. 1. Indian Mission rights-of-way wetland research plots.

rant. The end points of each transect line were marked with permanent stakes which allowed the same transect to be surveyed in subsequent years (Fig. 1).

Herbaceous plots 1 m square were laid out along the mid-line of each 2 m × 10 m shrub plot at 0 m, 5 m and 10 m. These three points were permanently marked with wire flags. At either end of the transect a 5 m buffer was left to reduce the edge effect of shading from the adjacent woodland at one end, and the travel effect of the maintenance corridor at the other (Fig. 1). Herbaceous vegetation was stem counted by species and percent cover estimated following species identification. All specimens were identified to genus and, where practical, to species. A prefabricated meter square made from 12.5 mm PVC schedule 40 plastic water pipe was used along the survey line, within which data were gathered.

In the tree plots individuals were identified to species where possible, counted and measured at diameter breast height (DBH). Woody specimens ≥5 cms DBH were considered trees, and further subdivided into desirable (D) and undesirable (U) species, as previously described. Woody specimens <5 cms DBH were considered shrubs and were identified to genus or species and the number of stems counted. Only when these species reach a stage ≥5 cms DBH are they controlled by the utility company.

A modified relative importance value (RIV), developed by Curtis (1959) in Mueller-Dombois and Ellenberg (1974), was applied to this study and used to compare the various species groups to each other, between seasons and years. The RIV was calculated by the equations:

FOR HERBS: RIV = (relative frequency + relative % cover)/2;

where relative frequency = f of a species/sum f of all species × 100; f = # plots in which a species is found/total # plots in the survey. Relative cover = (% cover of a species/% cover of all species) × 100.

FOR SHRUBS: RIV = (relative frequency + rel. density)/2;

Table 1. Indian Mission Conectiv Power Delivery ROW construction and herbicide treatment history 1992 to 1997

Year/Season	Treatment	Effected Quads	Notes
1992 Fall	Clear-cut (CC) Select-cut (SC)	NW, SE NE, SW	CC = tree stumps & shrubs mown to ground level SC = undesirable trees and shrubs removed
1993 Fall	Initial Herbicide Select-Spray (SS)	NE, SE	Code 031, foliage/hydraulic broadcast (upland) X670, backpack (wetland) NW, SW untreated (UT)
1994 Summer	Follow-up Herbicide Select-Spray	NE, SE	Same as 1993 in upland
1995	None	All	
1996	None	All	
1997 Summer	Follow-up Herbicide Select-Spray	All	Code 031G, foliage/hydraulic broadcast Code XG670 backpack wetland

UPLAND HERBICIDE CODES, MIXTURES and RATES

Code 031 1993 = 4.73L (1.25 US gal.) Accord* + 1.18dl (4 oz.) Arsenal + 1.89L (0.50 US gal.) Cleancut + 0.95L (0.25 US gal.) Weedar 64 + 1.18dl (4 oz.) 38F drift control in 378.5L (100 US gal.) water.

Code XG670 1997 = 4.73L (1.25 US gal.) Accord* + 4.14dl (14 oz.) Garlon 3A + 1.18dl (4 oz.) Arsenal + 56.78L (15 US gal.) Thinvert (total volume = 62.07L (16.4 US gal.)) in 378.5L (100 US gal.) water. Used in upland.

Code 031G 1997 = 4.73L (1.25 US gal). Accord* + 0.95L (0.25 US gal.) Garlon 3A + 1.18dl (4 oz.) Arsenal + 1.89L (0.50 US gal.) Cleancut + 1.18dl (4 oz.) 38F drift control in 378.5L (100 US gal.) water.

*Glyphosate applied at a rate of 10.44 L/ha (4 qts/ac), 53.8% active ingredient (a.i.).

TRADE NAMES OF HERBICIDES USED

Accord (common name: glyphosate isopropylamine), composition = 53% concentration of sopropylamine salt of N-[phosphono-methyl] glycine.

Arsenal, (family name: imidazolinone), composition = isopropylamine salt of imazapur (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridine carboxylic acid).

Garlon 3A, (common name: Triclopyr), composition = 3,5,6-trichloro-2-pyridinyloxyacetic acid.

Weedar (common name: 2,4-D), composition = dodecylamine + tetradecylamine salts of 2,4-D. (Ref: Meister and Sine, 1996).

Surfactants used were Cleancut, Thinvert and 38F used for drift control.

where relative frequency = as above for herbs; and relative density = (# individuals of a species/total # individuals of all species) × 100.

The RIV values for each species can be combined to provide totals for desirable (D), undesirable (U) vegetation and woody vine species groups for each season and year. A high RIV indicates that a particular species or species group was found to occur at a higher density relative to a species or species group having a lower RIV value.

Nomenclature used for herbaceous and woody species was taken from Brown and Brown (1972 and 1984), and for bryophytes, Shuttleworth and Zim (1967).

RESULTS AND DISCUSSION

The ROW through the wetland was established by clear-cutting trees and shrubs in the fall of 1992, using standard industry mechanical and hand-cutting procedures, except where the research quadrant treatments were installed (Fig. 1). Only in the access lane were the tree stumps ground down and the wood chips deposited. The vegetation changes that followed can be broken down into 6 groups for analysis:

A) *General overview.* The wooded wetland survey site was bisected by a stream, with one clear cut (CC) and one select cut (SC) tree quadrant on the north side and one each again to the south (Fig. 1). Within each 10 × 50 m tree quadrant were five 2 × 10 m shrub plots and within each shrub plot were three 1 m^2 herbaceous plots, making a total of 4 tree plots, 20 shrub plots and 60 herbaceous plots.

The species composition at baseline, immediately prior to ROW construction, was dominated by a mixed ash (*Fraxinus* sp. L.), swamp magnolia (*Magnolia virginiana* L.), and American holly (*Ilex opaca* Ait.) overstory with additional swamp maple (*Acer rubrum* L.), black gum (*Nyssa sylvatica* Marsh.), and yellow poplar (*Liriodendron tulipifera* L.). The understory was dominated by sweet pepperbush (*Clethra alnifolia* L.) with an azalea-winterberry-arrowwood shrub community association (*Rhododendron-Ilex-Viburnum*). Additional understory species of lesser abundance included greenbriar (*Smilax rotundifolia* L.), highbush blueberry (*Vaccinium corymbosum* L.), and swamp fetterbush (*Leucothoe racemosa* (L.) Gray). The ground herbaceous vegetation was dominated by *Sphagnum* moss and skunk cabbage (*Symplocarpus foetidus* Salisb.), with lizard's-tail (*Saururus cernuus* L.), sedges (*Carex* sp. L.), and spike-rush (*Eleocharis* R. Br.).

Suitable buffers were maintained from the perimeter of the survey transects and ROW margins and stream in order to reduce the influence of shading and soil saturation. Like treatments were established diagonally opposite each other in order to minimize the influence of sunlight.

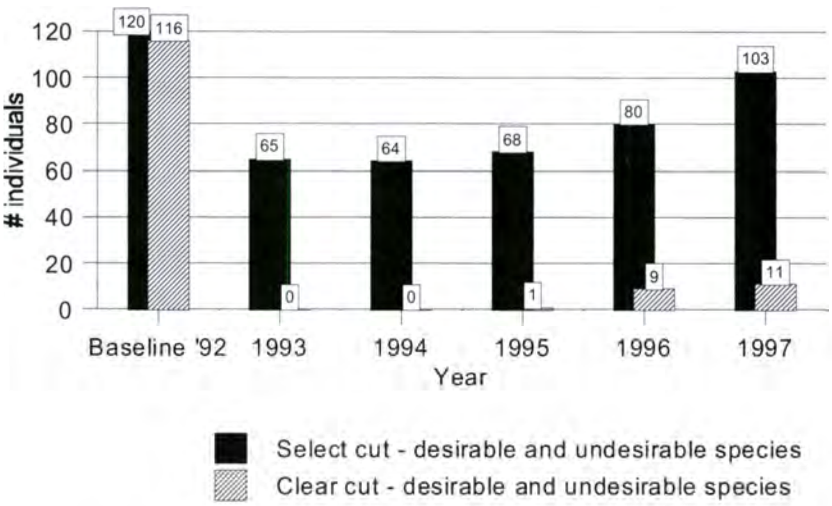


Fig. 2. Indian Mission wetland tree species stem count CC cf SC.

B) *Trees and shrubs* (≥5 cms DBH). All tall growing undesirable (U) tree species were eliminated from the study site immediately post-baseline due to the primary interventions of clear-cutting (the preferred utility treatment method in quadrants NE and SW) and selective-cutting (permitting agency suggested treatment method in quadrants NW and SE) in the fall of 1992. In the clear cut (CC) quadrants all trees and shrubs were cleared, but in the select cut (SC) desirable (D) trees like American holly, swamp magnolia and ash were allowed to remain, depending on their position across the ROW (see Arevalo-Camacho et al., 1997). All undesirable species (maple, black gum, and poplar) were removed in both treatments. The ratio of desirable to undesirable trees was approximately 50:50.

With the clearance of the overstory there was a major shift from tree species to shrub species, particularly sweet pepperbush, over the period of the survey in both treatments. Released by the lack of tree competition that limited the understory, the shrub/herbaceous vegetation came to dominate the sites equally in both the clear cut and the select cut. A total of 8 to 9 tree species (both U and D) were found consistently across the survey sites, half of which were undesirable and eliminated from the sites post-baseline. Undesirable trees did not start to reoccur in both the clear cut and the select cut until the fall of 1995 (third year post-treatment).

In this type of wooded wetland, undesirable trees naturally dominate over the desirable species, particularly in size as opposed to number. All large trees were hand cut, as opposed to mechanical cutting in an upland situation, which left a significant number of stumps, capable of sprouting, and younger trees, which were sampled >5 cms DBH in the latter years of the survey. Desirable and undesirable species numbers were even (D4:U4) at baseline, but physical biomass favored U-species. In an adjacent upland study carried out at the same time, the species ratio was D2:U10 at baseline. (Johnstone et al., 2002).

In the select cut (SC) plots, following initial construction in 1992, there followed a significant annual increase in total stem count after year 3 (Fig. 2). Species numbers remained constant, due to hand cutting vs. mechanical cutting in this ecologically sensitive site (Fig. 3).

In the clear cut (CC) plots the undesirable species did not started to attain tree dimension until 3 to 5 years post-construction, and stem count remained low in the treated plots due to IVM interventions (Fig. 3). No discernable difference was observed in the numbers of desirable trees in the treated versus the untreated plots, which indicated that the selective herbicide intervention in the year following construction was appropriately targeted by field crews. (CPD deems field crew education an integral part of an IVM program in order to achieve the stated goals).

An equivalent number (~250, range 200–500) of undesirable tree seedling species (<5 cms DBH and >2 RIV) in both the CC and the SC was found to remain constant from year 2 until the end of the study period, indicating that there was an ever-present natural cohort in this type of vegetation ready for recruitment (Fig. 4). These were mainly swamp maple, ash, and sweet gum. Once clear cut, species like black gum, holly, and yellow poplar do not appear as trees, even 5 years post-construction, since they are, presumably, slower growing and do not rapidly colonize by seed in this wetland environment. Yellow poplar, especially, propagates readily from seed in upland locations (Johnstone, pers. comm. 2004). Shorter trees, such as holly and magnolia, faired well in the select cut plots, despite the release in canopy, and were permitted to grow at the margins of the ROW, away from the wire zone.

Throughout the survey, irrespective of treatment, desirable trees appeared not to have good recuperative

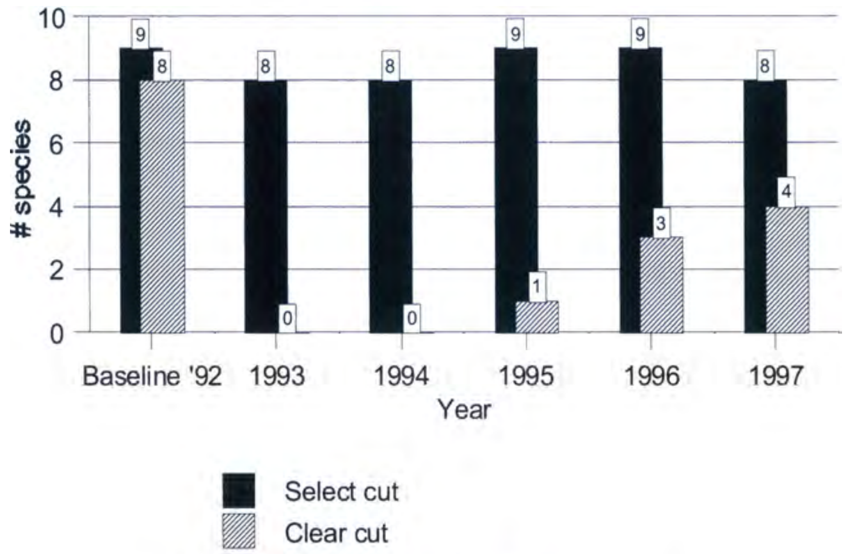


Fig. 3. Indian Mission wetland tree: number of species.

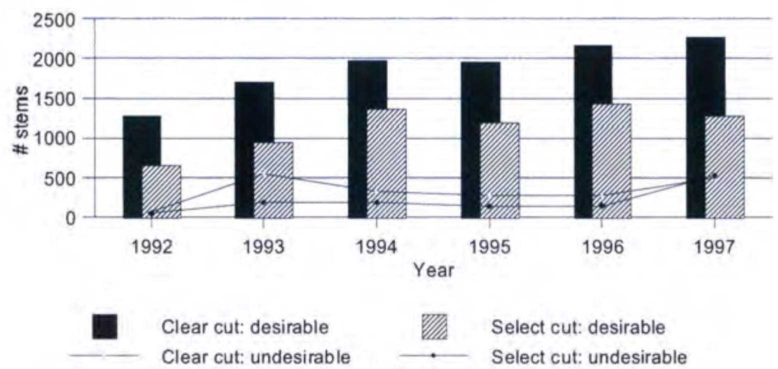


Fig. 4. Indian Mission wetland shrub: stem count CC cf SC.

capabilities in this changed environment. Conversely undesirable species such as swamp/red maple, ash, and sweet gum were found to persistently resprout and reseed, and were managed accordingly.

C) *Shrubs, woody vines and small trees* (<5 cms DBH). The total stem count of the shrub increased gradually over the 5-year study, especially in the clear cut (Fig. 4). The range in total species numbers over time varied from 17 to a peak of 26 species, occurring in 1995, 3 years post-treatment (Fig. 5). At the commencement of the study 19 species of shrubs were identified in all quadrants and by the end there were 21 species. This represented an overall gain of 10 species, with 5 (D2:U3) species being lost and 10 (6D:U4) gained. The CC retained the same 24 species over the study period (D17:U7) gaining 6 new species and losing 6. The SC had an overall gain of 4 species during the study period, with 23 found at baseline; a gain of 8 and a loss of 4. Twenty-two species persisted over the study period in both the treatments, 5 being lost and 9 gained, only 20% of which were U-species. This data presents a close correlation in species dynamics between the two treatments (NS).

An analysis of the quadrants by CC and SC pairs reveals some useful comparisons in the similarity of shrub succession between the two construction methods (Figs. 6a and 6b). The overall dominant shrub at baseline in both treatments was sweet pepperbush, which has an RIV index that is 50%–100% of the sum of the next 6 most common species (Fig. 6a). Both treatments showed a very stable pepperbush population, with a slight increase in RIV in the 2nd and 3rd years post-intervention. The next 6 most common shrubs (swamp azalea, winterberry, arrow-wood, greenbriar, high-bush blueberry, and fetterbush) also demonstrated a high degree of stability, showing no significant difference between the effect of full canopy release (CC), and no benefit from partial canopy retention (SC). A species and treatment comparison may be reviewed in Table 2.

Summation RIV showed close correlation between the CC and the SC (Fig. 7). The CC values were not significantly greater than the SC during the post-intervention period, and both were only slightly lower than the baseline (NS).

D) *Herbaceous vegetation, including succulent vines.* From the baseline fall data, herbaceous species in-

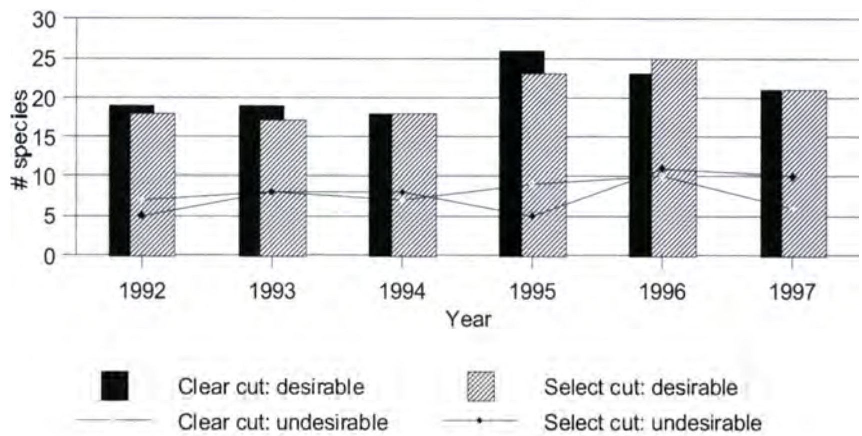


Fig. 5. Indian Mission wetland shrub: number of species.

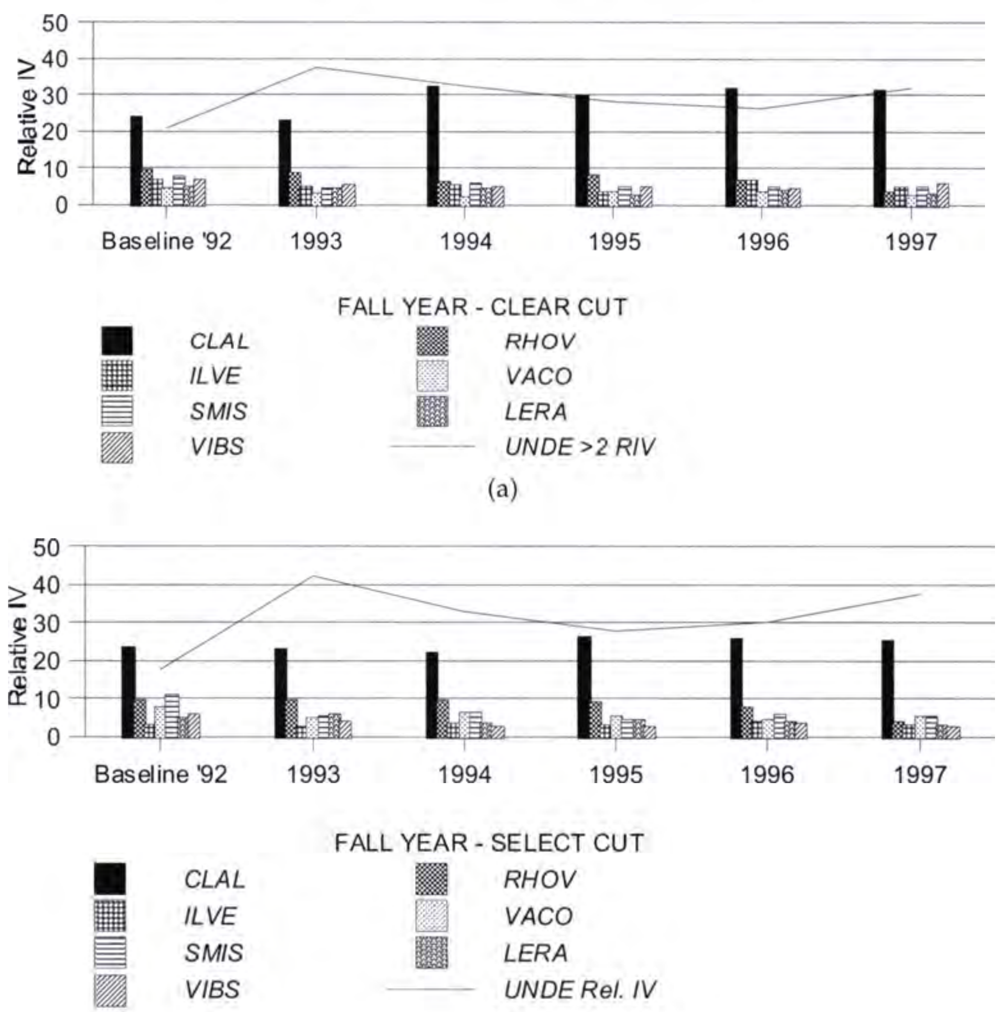


Fig. 6. Indian Mission wetland shrub: dominant individual species RIV.

creased from 11 to 42 in the SC, and 13 to 42 in the CC, the SC peaking in 1995 to 46 species and the CC to 49. This significant increase was followed by a high degree of consistency in species numbers for the duration of the 5 year study (range: CC = 42–49; SC = 38–43) (Fig. 8), exemplifying a rapid response by these species to canopy release from a large and varied seed bank that has remained dormant for decades.

Since no baseline spring data was taken, a comparison can only be made to the first spring season post-treatment. Herbaceous species increased from 21 to a total of 45 at the end of the study for the SC site;

Table 2. Indian Mission wetland: desirable shrub stem count

INDIAN MISSION WETLAND DESIRABLE SHRUBS >100 stem count/year.
Comparison of 5 year mean (0) post intervention (CC cf SC) 1993–1997 with 1992 baseline.

CLEAR CUT (CC) # stems					SELECT CUT (SC) # stems				
Species	Baseline	%	5 yr. 0	%	Species	Baseline	%	5 yr. 0	%
CLAL	561	51	1173.0	68	CLAL	186	33	575.2	56
RHOV	151	14	179.6	10	VIRE	95	17	112.6	11
ILVE	66	6	96.2	6	RHOV	69	12	91.4	9
SMIS	100	9	78.8	5	SMIS	101	18	60.2	6
VACO	71	6	53.2	3	VACO	40	7	55.6	5
LEUS	63	6	50.0	3	LEUS	24	4	43.6	4
VIRE	49	4	50.0	3	ILVE	18	3	41.2	4
VINU	16	2	33.8	2	VINU	5	1	27.4	3
ITVI	35	3	19.6	1	ITVI	29	5	23.4	2
Total	1112		1734.2		Total	567		1030.6	

KEY TO DESIRABLE ROW WETLAND SHRUB SPECIES:

Species code	Latin name	Common name
CLAL	*Clethra alnifolia*	Sweet Pepperbush
RHOV	*Rhododendron viscosum*	Swamp Azalea
VIRE	*Viburnum recognitum*	Smooth Arrow-wood
ILVE	*Ilex verticillata*	Winterberry
SMIS	*Smilax sp.*	Greenbriar
VACO	*Vaccinium corymbosum*	High-bush blueberry
LEUS	*Leucothoe sp.*	Fetterbush
VINU	*Viburnum nudum*	Smooth Witherod
ITVI	*Itea virginica*	Virginia Willow

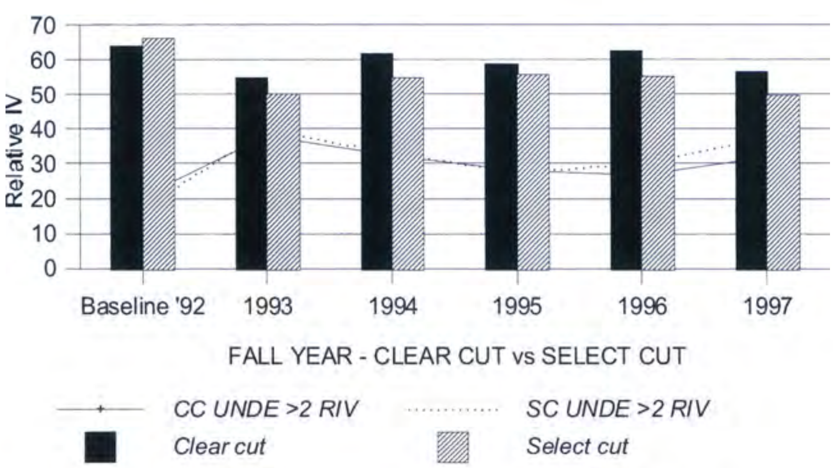


Fig. 7. Indian Mission wetland shrub: total shrub species CC cf SC.

the CC increase from 23 to 45 (range: CC = 23–45; SC = 21–45). Unlike the fall data, which immediately leveled out post-intervention, the spring data continued to increase, with some variability, for the study period (Fig. 8).

Only 1 species is lost in each of the CC and SC fall surveys; a wetland aster (*Aster* L. sp.) and water hemlock (*Cicuta maculata L.*), respectively. The spring surveys lost 3 species each over the 5 year period; wintergreen (*Chimaphila* Pursh), mint (*Mentha* L. sp.), and meadow rue (*Thalictrum* L. sp.) in the SC; water hemlock, greenwood orchis (*Habenaria clavellata* (Michx.) Spreng.), and loosestrife (*Lysimachia* L. sp.) in the CC. These species constituted only a few or single specimens and are either shade dependent or they were destroyed during site construction. It is interesting to note that species loss is <8% of the CC species, but 27% of the SC, of baseline. The surviving species are not shade dependent, as might be expected, but highly adaptable to varying light conditions.

The increase in the number of species is offset by a significant drop following construction intervention,

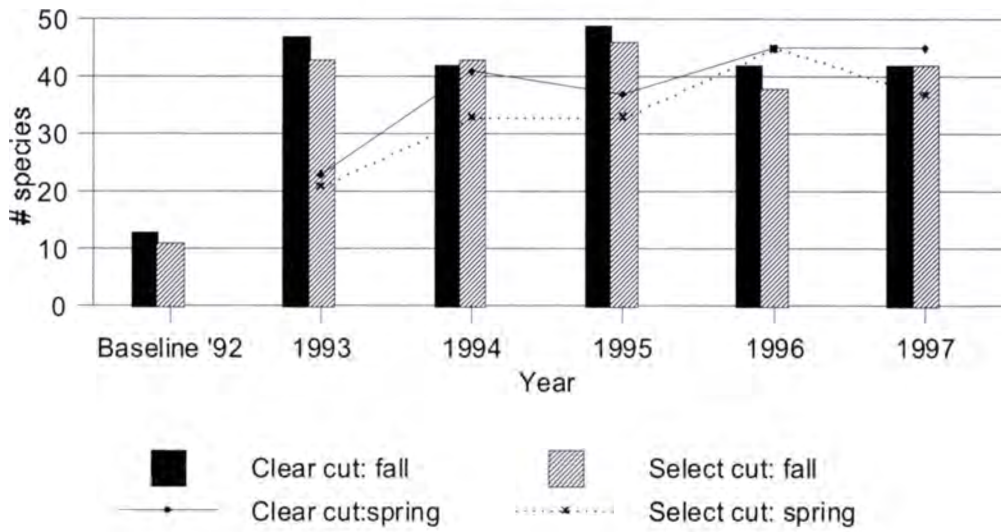


Fig. 8. Indian Mission wetland herbaceous: number of species CC cf SC.

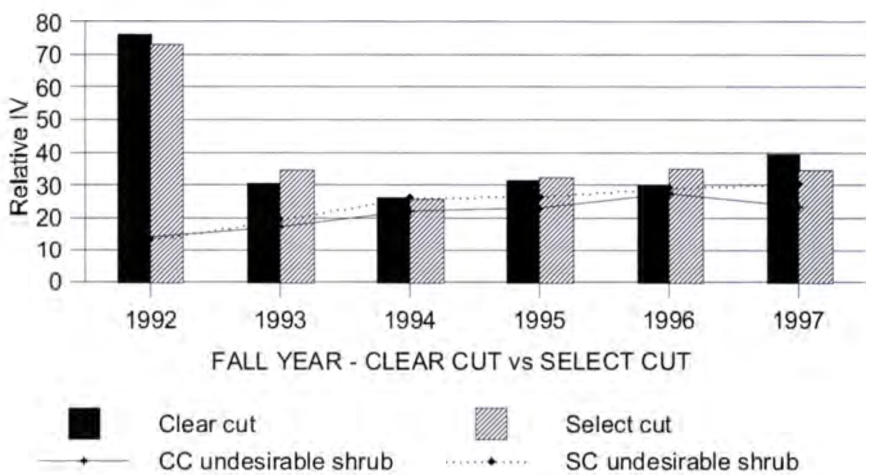


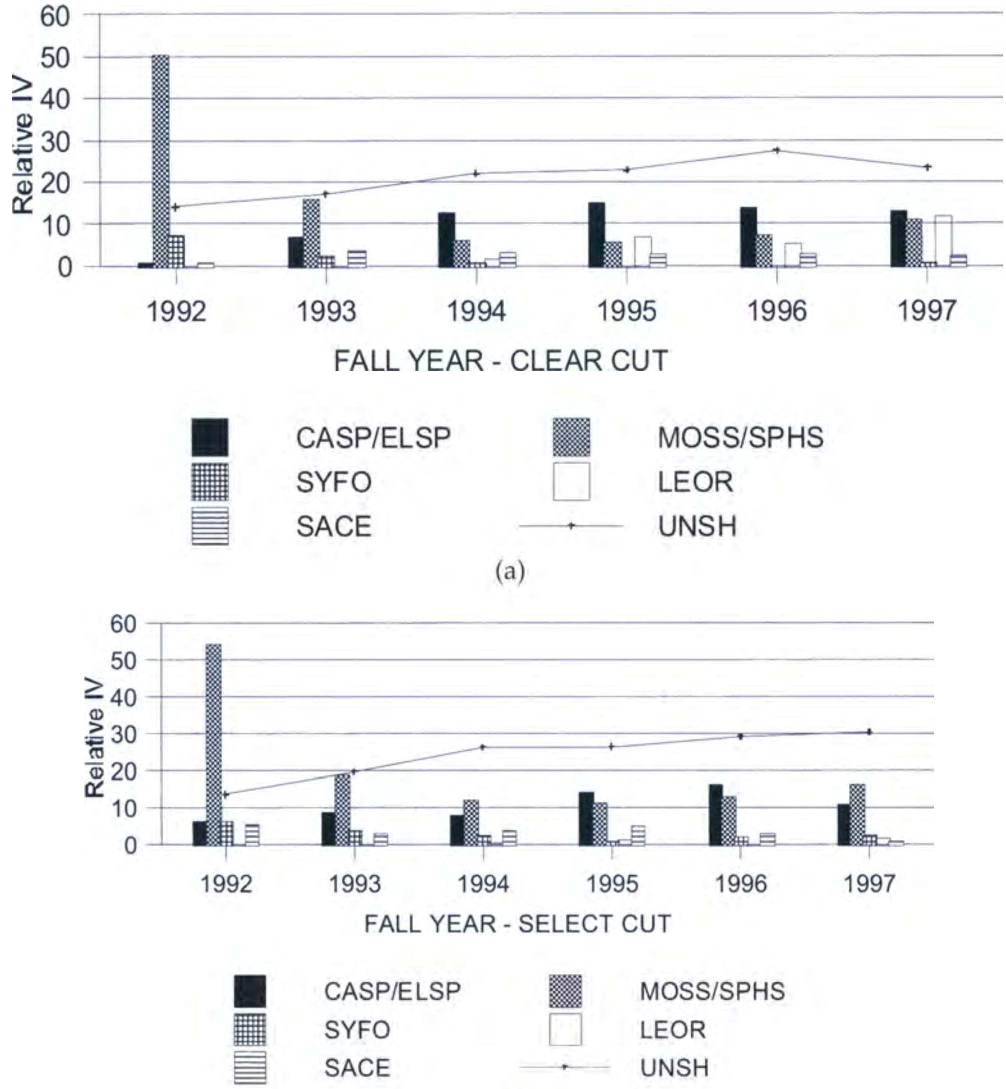
Fig. 9. Indian Mission Wetland Herbaceous: dominant species CC cf SC.

in the RIV by over 50% in both the CC and the SC (NS) (Fig. 9). Herbaceous species numbers started to peak in the 5th year of the study, a time when maximum colonization has generally occurred (Haggie et al., 2004). Inter-specific competition from herbs and shading from increased growth in the shrubs, subsequently initiated a decline.

At baseline the herbaceous vegetation comprised mainly of *Sphagnum* and other moss species and at this point total moss RIV was >50; in contrast the RIV sum of the next 6 dominant species was <50% of this (Figs. 10a and 10b). Upon release of the overhead canopy the moss community rapidly declines in both the CC and the SC for 4 years post-intervention, and only starts to recover in year 5 when some shade grows back from young U-trees, just prior to the next spot-spray intervention (Table 3). The moss/skunk cabbage community is replaced over time by sedges, spike rush, lizard's tail, and rice cut-grass. Skunk cabbage was able to maintain its presence in the SC, which provided sufficient shade for this species, but not the mosses. No differences (NS) in vegetation RIV were noticed between the CC and SC in either the spring or fall analyses nor in the total living herbaceous RIV analysis, although species specific differences were found as noted.

E) *Non-living material* (NLM). The herbaceous baseline data in the fall of 1992 consisted of a combination of open water, bare wetland muck soil and leaf litter that occupied the forest floor of the wooded wetland (CC = 90.5% and SC = 87.4% NLM). In the fifth year following construction, the average spring NLM percent cover was 27.4% in the CC and 25.0% in the SC; the fall NLM percent cover was CC = 22.4% and the SC = 33.2% (Fig. 11). This indicates a better amount of living plant ground cover in the fall for the CC, due to accumulation of biomass over the growing season, as compare to the spring data. Increased percent cover in the CC was evidently due to partial shading by the remaining trees in the SC.

The percentage of the open water and bare wetland (muck soil) in the CC was 89.8% at baseline in the



(b)

Fig. 10. Indian Mission wetland herbaceous fall: RIV dominant individual species.

herbaceous plots, and 5 years later, at the end of the study, only 4.7%. In the SC, the open water and muck soil was 87.4% at baseline, statistically the same, and at the end of the study 6.3%. Thus no significant difference (NS) was found between the two sites. The slight increase in bare wetland in the SC may be partly due to the shading and allelopathic effects of the remaining shrubs (Meilleur et al., 1994) and desirable trees (principally holly and magnolia).

This NLM component again demonstrates that in a wetland, as well as in an upland (Johnstone et al., 2002), environment, where utility ROW construction occurs, over 90% stabilization of the soil surface can occur as effectively where clear methods are employed as select cut.

F) *Wildlife implications*. To determine a gauge of comparative wildlife use in the different ROW preparation methods, a Wildlife Use Index (WUI), adopted by the U.S. Fish and Wildlife Service (USFWS), was adapted from the URI (Use Rating Index) developed by Martin, Zim and Nelson (1951). In order to make a valid regional comparison, the north-east and south-east URI data from Martin et al. was averaged. All trees were excluded from the WUI evaluation due to their incompatibility in a ROW. Trees such as oaks have a very high WUI (263), but only if allowed to grow to maturity, which is incompatible with ROW management. One limitation of the WUI is that not all species in the survey were evaluated by the USFWS. In such cases an assumed value of 1 was given.

A WUI was applied to the desirable dominant shrub and herbaceous species with an index ≥ 1 in order to assess comparative values for SC and CC (Fig. 12). WUI values were also computed to compare baseline data with the arithmetic mean of the 5 years post-intervention. At baseline, WUI of the CC quadrants was 14.6 (shrubs = 10.8, herbaceous = 3.8) and SC quadrants was 29.5 (shrubs = 15.3, herbaceous = 14.2). In the fifth year post-construction the CC mean was 58.8 (shrubs = 10.4, herb = 48.4) and the SC was 53.3

Table 3. Indian Mission wetland: comparison of relative importance value (RIV) in the five dominant herbaceous species

INDIAN MISSION WETLAND: 5 DOMINANT HERBACEOUS FALL RIV >1.
Comparison of 5 or 4 year mean (0) post intervention (CC cf SC) 1993–1997 with Fall = 92 baseline.

	Relative Importance Value (RIV)			Relative Importance Value (RIV)		
		Spring: 4 year mean			Fall: 5 year mean	
Species	Baseline0	CC	SC	Baseline0	CC	SC
CASP/ELSP	3.4	9.9	8.8	5.4	12.4	11.5
SPHS/MOSS	21.9	5.2	7.4	54.2	9.3	14.2
SYFO	35.5	10.9	16.8	7.1	0.8	2.2
LEOR	0	2.0	0	0	5.1	0.6
SACE	2.4	7.8	5.6	3.2	3.0	3.0
UNSH	10	23.2	24.0	13.8	22.6	26.4

KEY TO HERBACEOUS (desirable) WETLAND SPECIES:

Species code	Latin name	Common name
ELSP	*Eleocharis sp.*	Spike-rush
CASP	*Carex sp.*	Sedge
SPHS	*Sphagnum sp.*	Sphagnum moss
MOSS	*Bryophytes*	Other moss species
SYFO	*Symplocarpus foetidus*	Skunk Cabbage
LEOR	*Leersia oryzoides*	Rice cut-grass
SACE	*Saururus cernuus*	Lizards Tail
UNSH		Undesirable shrub species

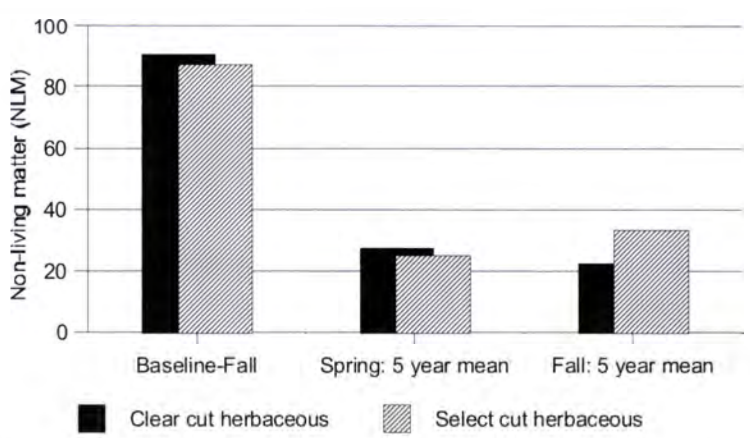


Fig. 11. Indian Mission wetland: dead plant residue (NLM) herb: CC of SC spring and fall.

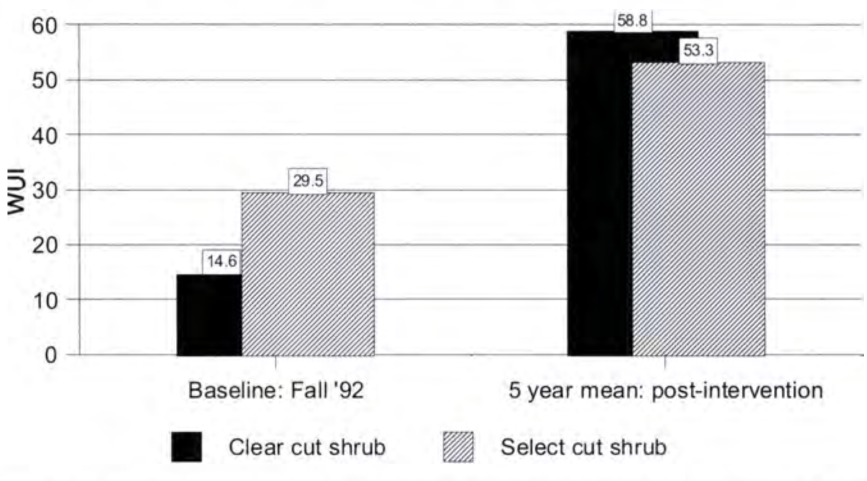


Fig. 12. Indian Mission wetland: wildlife use index combined shrub and herbaceous, CC cf SC.

(shrubs = 12.3, herbs = 41.0) (Fig. 11). The overall increase in the WUI can be attributed to a significant increase in the shrub/herbaceous vegetation with moderate WUI values. The shrub species having a medium URI included sumac (*Rhus* L.) (29), greenbriar (20), blueberry (41), and grape (*Vitis* L.) (45). The herbaceous species included *Carex* sedges (41), spike rush (30), and rice cut-grass (*Leersia* Sw.) (18) (Fig. 12). The desirable trees do not have a high wildlife value, the exception being American holly, URI = 16. The CC demonstrated a significant increase in WUI which at the end of the study was equal to, or greater than, the SC.

CONCLUSIONS AND RECOMMENDATIONS

The primary question of this investigation was whether adequate natural vegetation would colonize a clear-cut (CC) as opposed to a selective cut (SC) newly constructed utility ROW through ecologically sensitive habitat, such as a wooded wetland. Data showed that early vegetation recovery (evaluated by % cover, stem count, and RIV) in the CC quadrants was sufficient to reduce erosion equally as effectively as compared to the SC method. Shrub and herbaceous colonization of the CC areas was sufficient to achieve 75% living plant cover (LPC) over the 5 year study period, while the SC had more area of bare wetland (71% LPC). This amount of plant colonization can occur provided ROW clearance through such environments is conducted by hand or with the use of light mechanical equipment. This study suggests that the erosion control rationale for permitting agency restrictions on clear cutting and the preferences for selective cutting, may be misguided. The study showed that by solely evaluating the shrub and herbaceous colonization there can be equal or more potential plant cover and wildlife value after 5 years in a CC as opposed to a SC. Changes in desirable shrub RIV and stem count all demonstrated comparable species occupation, species maintenance, species colonization and extinction in both treatments. A general evaluation of the shrub stem count and RIV revealed that the CC and SC quadrants did not significantly vary and both colonized well three years after ROW construction and almost completely by the end of the study.

When select-cutting trees careful consideration should be given to the condition, growth stage, and type of tree selected. Tree density and tree height should be considered as well as the age of the woodland as a whole. Maintenance and applicator crew education was found in this study to be of great importance in obtaining the appropriate vegetation types in order to establish the viable community desired for maintenance access and electrical reliability.

Following this study, it is now possible to make a general prediction of the eventual shrub/herbaceous community that will evolve following site preparation of a utility ROW in a mid-Atlantic coastal plain wooded wetland, provided there is judicious follow-up of selective herbicides to undesirable vegetation. Any projection must be founded upon adequate baseline data. We demonstrate that no artificial replanting is necessary to establish baseline ground cover following construction. Rather, with the release of the overhead canopy and with the IVM guidelines indicated, this study revealed a 7-fold increase in the herbaceous plant community. This can be achieved as effectively using a clear-cut or select-cut method of ROW establishment, as long as a careful examination is made of the existing plant community prior to construction (baseline) and knowledge has been acquired on the effects of cutting upon different species. This study does not demonstrate that clear-cutting is better than selective-cutting. It simply shows that there are no discernible differences between clear-cut and selective-cut methods in ROW construction and their respective plant composition 5 years post-construction.

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REFERENCES

Arevalo-Camacho, J., J. Roig-Soles, C.M. Juaristi, F.G. Manzaneque, E.B. Bermejo, F.D. Lozano, J.M. Pecino, S.M. Herranz, and L.M. Rivero. 1997. Study of the Iberian flora compatible with power lines, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. Elsevier Science Ltd, Oxford, UK. pp. 511.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1987. Development of plant cover diversity on an electric transmission right-of-way, in Proc. of the Fourth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: W.R. Byrnes and H.A. Holt. Indianapolis, IN. pp. 595.

Brown, M.L. and R.G. Brown. 1984. Herbaceous plants of Maryland, Port City Press, Baltimore, MD. pp. 1127.

Brown, R.G. and M.L. Brown. 1972. Woody plants of Maryland, pp. 347. Port City Press, Baltimore, MD.

Cain, N.P., 1997. Old field vegetation for low maintenance highway rights-of-way, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. pp. 511.

Byrnes, W.R., W.C. Bramble, R.J. Hutnik, and S.A. Liscinsky. 1993. Right-of-way site factors responsible for resistance of certain plant cover types to tree invasion, pp. 76–80, in Proc. of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: G.J. Doucet, et al. New Orleans, LA. Hydro-Quebec, Montreal, Quebec. pp. 558.

Chasko, G.G. and J.E. Gates. 1982. Avian habitat suitability along a transmission-line corridor in an oak-hickory forest region. Wildlife Monograph, 82: 41.

Curtis, J.T. 1959. The vegetation of Wisconsin. An ordination of plant communities. Univ. of Wisconsin Press, Madison. pp. 657.

Delorey, A. 1992. The power line ROW: an unexpected place to find many nesting birds. Birding, 24(6): 365–367.

Draxler, R., D. Uther, G. Praxl, and F. Hofbauer. 1997. New aspects of rights-of-way management for high-voltage power lines, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. pp. 511.

Finch, K.E. and S.D. Shupe. 1997. Nearly two decades of integrated vegetation management on electric transmission rights-of-ways, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. pp. 511.

Garant, Y., J. Domingue, and F. Gauthier. 1997. Effectiveness of three vegetation control methods in establishing compatible plant species in powerline ROW in northeastern Quebec, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. pp. 511.

Haggie, M.R., R.A. Johnstone, and H.A. Allen, 1997. Vegetational succession following a broadcast treatment of glyphosate to a wild reed stand in a utility right-of-way, in Proc. of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.R. Williams, et al. New Orleans, LA. pp. 511.

Haggie, M.R., R.A. Johnstone, and H.A. Allen, 2004. Comparative analysis of herbaceous plant species recurrence following a wildfire and a broadcast herbicide treatment along adjacent sections of an electric transmission right-of-way (unpublished).

Hallmark, S. 1996. IVM: a competitive tool. Electric Perspectives. May-June, pp. 16–28.

Horsley, S.B. 1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod and aster. Canadian Journal of Forestry Research, 7: 205–215.

Ireland, W. and E.D. Matthews. 1974. Soil survey of Sussex County, Delaware. U.S. Government Printing Office, Washington, D.C. pp. 74.

Johnstone, R.A. 1997. Personal communication. Supervisor of Forestry, Delmarva Power & Light Co., Salisbury, MD, 3 January.

Johnstone, R.A. 2004. Personal communication. System Forester for Conectiv Power Delivery, Newark, DE., 5 March.

Johnstone, R.A., M.R. Haggie, and H.A. Allen. 2002. Tree, Shrub and Herb Succession and Five Years of Management Following the Establishment of a New Electric Transmission Right-of-Way through a Mixed Woodland, in Proc. of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Eds: J.W. Goodrich-Mahoney, et al., Calgary, AL. pp. 955.

Martin, A.C., H.S. Zim and A.L. Nelson, 1951. American Wildlife and Plants. A Guide to Wildlife Food Habits: the Use of Trees, Shrubs, Weeds and Herbs by Birds and Mammals of the United States. Dover Publications Inc., NY. pp. 500.

Meilleur, A., H. Veronneau, and A. Bouchard. 1994. Shrub communities as inhibitors of plant succession in Southern Quebec. Environmental Management, 18: 907–921.

Meister, R.T. and C. Sine, eds. 1996. Farm chemicals handbook. p. C196. Meister Publishing Company, Willoughby, OH.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons Inc., NY. pp. 547.

Odum, E.P. 1971. Fundamentals of ecology. W.B. Saunders Co., Philadelphia, PA. pp. 574.

Putnam A. and Chung-Shih Teng. 1986. The Science of Allelopathy. John Wiley & Sons Inc., NY. pp. 317.

Shuttleworth, F.S. and H.S. Zim. 1967. Mushrooms and other non-flowering plants. Western Publishing Co., Inc., Racine, WI. pp. 160.

Smith, R.L. 1966. Ecology and field biology. pp. 686. Harper & Row, New York, NY.

Wildlife Habitat Enhancement Council. 1992. The economic benefits of wildlife habitat enhancement on corporate lands. Wildlife Habitat Enhancement Council, Silver Spring Maryland, 61 pp.

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Pepco's Environmental Stewardship on Transmission Line Right-of-Way Vegetation Management

Stephen M. Genua

The Potomac Electric Power Company (Pepco) is an investor-owned utility producing electricity for 1.9 million people in Washington, D.C. and suburban Maryland. Unlike many other utilities around the United States, Pepco owns most of its 10,000 acres of transmission line rights-of-way. This provides us with a great deal of latitude in their use as part of the company's future growth and expansion. At the same time, we are afforded the opportunity to be industry and community leaders in the environmental stewardship of these valuable properties. These rights-of-way (ROWs) traverse many different ecological systems, from streams, rivers, non-tidal wetlands, tidal wetlands, bogs, meadows, and shrub-scrub, to forests. Often, sensitive species are found only along these ROWs, due to development and population expansion limiting their spread. The transmission lines are fingers through many communities and often values vary from community to community. Balancing the need to maintain a reliable source of electricity with ecological stewardship and community needs is challenging and rewarding. Our greatest successes have been where we have engaged the community to achieve solutions that satisfy most. As a company, we could have done less. However, we have chosen to be good stewards of the environment and to show, through example, that environmental stewardship is good business. Our membership in the Anacostia River Business Coalition allows us to be mentor to others along the Anacostia River. Businesses and community groups that have less experience and success can learn from our example. Through example we demonstrate means of reducing pollution, enhancing the environment, and achieving recognition from others. While natural resource management along Pepco's ROWs has paralleled that of the Chesapeake Bay Initiatives Program, it has posed unique challenges along the transmission line R/W's. Our transmissions line ROWs cover over 10,000 acres in five Maryland counties, numerous cities and towns, and the District of Columbia. Pepco's ROWs are essential for the safe and reliable transmission of electricity. Tall-growing trees, commonly referred to as undesirables, naturally invade and can eventually dominate ROWs, posing a threat to electric service reliability. The principal vegetation management objective is to remove these undesirable plants and promote the growth of low-growing, relatively stable plant communities. Desirable plants are compatible with electric system reliability and, we believe, are environmentally appealing and beneficial to wildlife.

Keywords: Vegetation management, ROW, transmission line, environmental stewardship

INTEGRATED VEGETATION MANAGEMENT PROGRAM

Pepco utilizes various management tools to control and maintain the vegetation on the ROWs. Many factors affect the prescriptive analysis for the stewardship of 10,000 acres (330 miles) of transmission line ROWs. The following are the primary programs used to monitor and maintain the ROWs throughout the Pepco overhead transmission system:

- *Aerial Inspection*. A contractor patrols the designated transmission and sub-transmission (circuits) by air. The helicopter patrol occurs twice a year, during the spring and winter. The contractor inspects the facility for unauthorized activity, erosion and vegetation

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problems, as well as for broken insulators and wires or other hardware.
- *Barricade and Debris*. This program is used for removing illegally dumped debris from Company property, the construction of barricades to prevent vehicles from trespassing onto the transmissions line ROWs and soil restoration to prevent erosion.
- *Brush Control*. The primary purpose of this program is to control undesirable trees with herbicide application. In addition to the herbicide work, there will be other vegetation control work, both manual and mechanical. This also includes some tree trimming and other miscellaneous work.
- *Conflict Tree*. This work is primarily the trimming and removal of those trees which are outside the bounds of the transmission line ROWs that, if the tree fell toward the transmission facilities within the next 10 years, could damage those facilities or cause an interruption in service.
- *Tractor Mowing*. In this program, the contractor mows the grass and weeds on Pepco's R/W's. This is usually in the more urban areas, or where housing developments are adjacent to the ROWs. The work is typically performed with a farm tractor pulling a bush hog mower.

INCIDENT

During 1998, we experienced an electrical outage on one of the 230kv circuits due to a single tree that grew into the wires. Six other trees were found burning in the wires. A system-wide aerial and ground inspection revealed that approximately 350 trees were considered too close to the wires and had to be removed before the next growing season. The entire vegetation management program was reevaluated and we concluded that more intensive (control of the vegetation) ROW maintenance practices must be achieved. The vegetation density of undesirable species was too high. See Appendix A for lists of desirable and undesirable species of vegetation. Test plots revealed in many locations 25,000 to 30,000 stems per acre. A reasonable manageable level of 2,000 stems per acre is acceptable. The heights of a majority of the undesirable species were over 10 feet, upwards to 35 feet. The dense, high-growing vegetation could fuel an out-of-control fire, resulting in damage to the towers, wires and degradation of reliability.

In order to successfully recapture our ROWs, three goals must be achieved:
- Reduce the stem density of undesirable species and undergrowth, which makes our ROWs inaccessible and more costly to maintain.
- Reduce the height of all species to less than 10 feet, to improve electric service reliability.
- Extend all management practices to the edge of the transmission line ROWs, to recapture the full extent of the ROW and to reduce encroachments of vegetation.

RESOLUTION

To reach our goals, we developed the program of meadow management, a low-profile shrub/scrub community. The initial phase of this program is to mow (a one-time process) all vegetation and treat the area with herbicide to limit the undesirable type of woody species from re-sprouting. The ROWs are then maintained on a four-year cycle. Afterwards, only a selective basal application of herbicide will be used to treat the undesirable species and any undesirable species over ten feet will be removed. The long-term effect of this meadow management program will be a low-profile shrub/scrub plant community that is both beneficial to wildlife habitat and compatible with providing safe and reliable electric service.

Pepco line crews regularly consult with the Environmental Stewardship Team to ensure that the work is being done properly. Due to wildlife concerns, each year, Pepco refrains from mowing between April 15th through August 15th, and resumes during fall and winter when there is minimal impact on nesting, newborn and small animals. Pepco has also included a representative from the Maryland Department of Natural Resources (MDNR) as a participant on its Environmental Stewardship Team. The Wildlife Habitat Council (WHC) visited seven different transmission ROW sites in May 2000 to review our progress to date.

Wildlife management plan

The Transmission Rights-of-Way, cover approximately 10,000 acres are roughly broken down into 7,000 acres in brush or shrub/scrub; 2,000 acres in pasture, roads, and miscellaneous (these areas receive only minor maintenance); and 1,000 acres in mowed grass. The 7,000 acres in shrub/scrub form the basis for the habitat enhancement program.

New approaches and incentives are evolving to increase value of the R/W's through management of property based on ecological resource valuation. We have found that practicing environmental stewardship of our ROWs encourages partnering with wildlife support groups, environmental government agencies, and other ecological interest groups to achieve our corporate goals. In fact, most of the interests that drive our environmental partners fit Pepco Holdings Incorporated's Best Practices for the safe and reliable transmission of electricity.

The company has a well-established relationship with the Patuxent Research Refuge that allows management of the ROW that crosses the Refuge land and provides for control of undesirables while providing long-term research and habitat management opportunities for Patuxent Research Refuge staff. A project with the Refuge is building an osprey hacking tower at the National Wildlife Visitor Center near the Transmission Vegetation Management demonstration area.

Transmission Environmental Stewardship Initiatives

The following Stewardship Initiatives complement the initiatives at other company sites, represent a continuation of Pepco's commitment to environmental excellence, and are examples to others in our community and the utility industry:

Riparian Enhancement

In October 1996, the Chesapeake Executive Council, which includes the governors of the three bay states, the mayor of the District of Columbia, the Administrator of the U.S. Environmental Protection Agency and the chairman of the Chesapeake Bay Commission, adopted a long-term goal of protecting the bay's tributaries through establishment of vegetative buffers. More specifically, the Council plans to plant 2,010 miles of forest buffers along stream banks and shorelines by the year 2010.

In a joint project with the MDNR-Forest Service, Pepco currently is working with the Anacostia Watershed Forester, Bernadette Turner, in selecting the best sites for riparian enhancement. The Burtonsville to Takoma 230kv transmission line right-of-way has been targeted as a primary watershed area that feeds the Anacostia River. Two project areas have been completed, on the crossings of Sligo Creek and Paint Branch, both tributaries to the Anacostia. Sligo Creek is unique in that it contains the only self-sustaining population of brown trout in the metropolitan area. Our plans for 2000 will be to establish riparian buffers at other Anacostia River tributaries including the Northwest Branch, Little Paint Branch and Indian Creek. Pepco's Transmission Construction and Project Management and Natural Resources Management Departments, partnering with the MDNR, have already planted approximately 250 low-growing trees and plants alongside streams. These areas have been established as sensitive areas-no mow zones, with appropriate signage. Pepco's goal is to maintain or develop a minimum of a 50-foot buffer on both sides of each water crossing along our ROWs.

Project Habitat

Project Habitat is a nationally recognized program sponsored by the chemical company BASF. This program establishes rigorous criteria which utilities meet in their right-of-way management practices that promote and enhance wildlife habitat. Several wildlife groups support and co-sponsor this program: Quail Unlimited, Buckmasters, National Wild Turkey Federation, and Butterfly Lovers International. Pepco's management practices are consistent with these criteria, and we have been selected as a partner in this program.

Wild Turkey Habitat

Pepco currently is working with the Maryland Department of Natural Resources, Southern Region, Natural Resource Manager at the Myrtle Grove Wildlife Refuge in Charles County, to create and enhance an area for wild turkey habitat along the Burches Hill to Moss Point 500kv transmission line right-of-way. This will utilize a "prescribed burn" management practice to control the leaf and wood litter in preparing the area for planting clover. Approximately 14 acres will be involved in the total project. The clover will provide cover and a food source for young turkey. Once established, this area will be used as a demonstration site and serve as part of the Maryland Department of Natural Resources educational program to promote wild turkey habitat, as part of an interpretive trail with informational signage.

Butterfly Enhancement Project

In western Montgomery County, Pepco is enhancing an area on the Dickerson to Potomac River 230kv transmission line right-of-way to provide butterfly habitat. Butterfly populations are an integral part of this complex community along the ROW as they serve to pollinate flowers, provide food for wildlife, and add to the beauty of nature's surroundings. The meadow management program calls for removal of all the trees under the transmission lines in selected areas, mowing with a bush hog, and using herbicide to prevent rapid regeneration of all woody perennials the first year. This allows the dormant annual and perennial seed to germinate and grow. The second year, and thereafter, all woody perennial seedlings of taller species are spot-treated with herbicide. In this manner, the low-growing wildlife habitat can be reestablished and maintained. About three acres are presently set aside for this project, and signs are being prepared.

In this partnership with the Washington Area Butterfly Club, the International Butterfly Breeders Association and Maryland-National Capital Park and Planning Commission, we will selectively introduce as many butterfly nectar and larva host plants as possible, along with the naturally-occurring herbaceous vegetation. Approximately six acres on the right-of-way were timbered, mowed and treated in the spring of 1999.

BayScapes and Raingardens

On the Bowie to Oak Grove 230kv transmission line right-of-way, in City of Bowie, Prince George's County, Pepco is developing a BayScapes and wildflower area. This partnership with the City of Bowie and the U.S. Fish & Wildlife Service BayScapes Coordinator, will enhance an area that is visible from both residential and commercial areas and a major highway (Maryland Route 450). The project will be jointly funded; however, the majority of the low-growing herbaceous vegetation that is already established is the result of Pepco's Integrated Vegetation Management Program.

Area Bogs

Pepco is working with the Maryland Department of Natural Resources (MDNR), Wildlife Heritage Division, to protect, preserve and enhance several bogs that have been identified along the transmission line rights-of-way. On the Burtonsville to Takoma 230kv right-of-way in Prince George's County, researcher Waldo L. McAtee identified the Magnolia Bog as early as 1918. Even though the size of this major bog area has been greatly reduced by development over the years in the Calverton area, what remains of the bog is on Pepco transmission line ROW. Pepco has installed a super silt fence around this area to protect this sensitive area, added signs to preclude accidental intrusion, and is managing the site to prevent additional losses. Three other known bogs, Piney Branch, Piney Branch Barrens and North Brice, have been given special attention. In these areas, the tall woody plants are selectively mowed, and the re-growth is selectively treated. The bog areas were flagged, and signs and barricades are being installed to limit access to the sensitive areas. These bogs sometimes contain rare and endangered plant species.

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A Broad-Based, IVM Approach to Right-of-Way Management on Long Island, NY

Lawrence S. Ferrandiz

Prevailing political and social environments within which utility foresters must operate have become increasingly complex. This is particularly true in suburbs, where residential expansion brings new neighbors to transmission ROWs, and therefore new stakeholders in the management decisions that foresters make. The Long Island Power Authority (LIPA) provides electric service to approximately one million homes and businesses on Long Island, NY. A steep gradient in population density, from over 5000 persons per square mile to less than 200, runs eastward over the 100 mile length of the service territory. Differences in land use patterns, political divisions, groundwater management zones, and land ownership also exist, necessitating the abandonment of any "one size fits all" approach to the management of overlying rights-of-way (ROWs). Integrated Vegetation Management (IVM) provides the forester with a range of techniques to manage ROW vegetation that can accommodate the varying interests of stakeholders along the ROW. On Long Island, the specific IVM techniques used are influenced primarily by highly variable soil moisture, with xeric conditions favoring mechanical methods and mesic conditions favoring an environmentally responsible chemical approach. In this manner LIPA limits it overall use of herbicides. By evaluating soil conditions, property ownership, and land use, LIPA selects and deploys various IVM methods. This broad-based IVM approach strives to balance cost, legal considerations, public acceptance, and environmental impacts.

Keywords: Right-of-way, integrated vegetation management, IVM, soil, land use, suburbs, Long Island Power Authority, LIPA

INTRODUCTION

Prevailing political and social environments within which utility foresters must operate have become increasingly complex. This is particularly true in suburbs, where residential expansion brings new neighbors to transmission ROWs, and therefore new stakeholders in the management decisions that foresters make.

Methods of chemical and mechanical treatments to rights-of-way are well known to practitioners of integrated vegetation management. This paper does not address details of IVM methodology, but rather focuses on an example of how the concept is applied in a suburban utility setting.

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LONG ISLAND HISTORY AND GEOGRAPHY

Long Island's population "Boom"

Long Island, New York, is perhaps the quintessential American suburban setting. Just east of New York City, it provides ready access to the City's commerce, a strong local economy, and diverse housing and recreational opportunities. LIPA primarily serves two counties on Long Island – Nassau and Suffolk, along with a very small section of nearby Queens County (NYC).

Soon after World War II, many returning servicemen settled on Long Island to begin their families, where large tracts of farmland were being converted over to new housing. Levittown, established in 1947 in eastern Nassau County, was the first of thousands of affordable housing developments, which are now a familiar sight across the American landscape. With these and thousands of other housing units available, the Island's population grew, with an economy primed by two giant engines – New York City's commerce and Nassau

County's thriving aircraft industry, which grew up on it's treeless "Hempstead Plains."

Beginning in the early 1970's, the "baby boomers," children of the World War II generation, began to raise families of their own. With housing in western Long Island becoming ever more expensive, many moved to Suffolk County, most to the Township of Brookhaven, where affordable housing developments were being built on former Pitch Pine forestlands. Brookhaven, in central Long Island, had the distinction of being America's most rapidly growing township during the 1960's and 1970's.

During all of this time, the Island's growing need for electric power was met by the Long Island Lighting Company. In 1998, the Company's physical assets were acquired by the Long Island Power Authority, a New York State Public Agency. The Long Island Power Authority (LIPA) currently provides electric service to approximately one million homes and businesses on Long Island.

Long Island geography and ROW management

Long Island's history of development has been characterized by ever eastward expansion, so that a steep gradient in population density, from over 5000 persons per square mile to less than 200, now runs eastward over the 100-mile length of the LIPA service territory. In addition, differences in soils, land use patterns, political divisions, groundwater management zones, and land ownership also exist, necessitating the abandonment of any "one size fits all" approach to the management of overlying ROWs.

Demographic and land use patterns on Long Island greatly influence ROW management techniques, such that they are compatible with the surrounding communities. In western Long Island, for example, densely populated communities had little available space for dedicated electric rights-of-way, so any transmission lines were built on poles alongside secondary highways. Being on shared easements along with other utilities and municipal services, LIPA only trims trees for clearance along these lines, and no typical ROW management is performed. This is true for most of LIPA's Nassau County service territory.

In Suffolk County, however, more open land was available during the expansion of the electric system. Therefore, more traditional "cross country" rights-of-way were either purchased or procured in easement. Lands on or adjacent to these Suffolk County rights-of-way vary from densely populated residential neighborhoods not unlike those in western Long Island, to low density residential, light industrial, commercial, agricultural, recreational, and remote areas. These lands are occupied by persons who have similarly varying interests in how the adjacent right-of-way is managed. In recent decades, thousands of residential homes have been built directly adjacent to electric rights-of-way in Suffolk County.

Being formed by the terminal moraines of two separate glaciers, Long Island has highly variable soil conditions. Soils range from well drained loams located more to the north and west, to excessively drained sands more eastward and southward.

The specific ROW management techniques used are influenced by these variable soil moisture conditions, with xeric (dry) conditions favoring mechanical methods and mesic (moist) conditions favoring an environmentally responsible chemical approach. Growth rates of trees and brush on Long Island's driest soils can be such that treatment intervals of eight years or more suffice to maintain adequate access and clearance. Therefore, the cost of mechanical techniques is not nearly as prohibitive as it would be on moister and more productive soils. On moister soils, brush develops rapidly and mechanical methods become more expensive.

ROW management practices on a growing Long Island

LILCO, the former owner of Long Island's transmission system, was confronted with the problem of managing brush in these new suburban communities. Older methods of hand cutting and herbicide application resulted in "weedy" looking areas within otherwise manicured neighborhoods. In an effort to address this, LILCO initiated a "ROW Beautification Program" in the mid-1960's. Fee-owned rights-of-way were cleared, grubbed, graded, and seeded to make them look more like their surroundings. Mowing was performed, in some places up to five times per year, to keep them attractive looking. At its' peak, nearly 800 acres of turf grasses were maintained under this program. Rights-of-way in more remote areas continued to be managed by hand cutting, herbicides, and by evolving methods of heavy-duty mechanical mowing.

In the late 1970's, the "agent orange" controversy raised awareness of 2,4,5-T being used on lawns and in utility forestry programs. Just a few years afterward, Long Island was home to two major pesticide-related incidents – the poisoning of thousands of Suffolk County wells with Temik insecticide, and the State-ordered demolition of a home which was improperly treated with Chlordane. Both events received extensive local and national media coverage. LILCO, in an effort to reduce criticism and legal exposure, discontinued the general use of herbicides for ROW management, opting for mechanical treatments only on rights-of-way. LILCO's 1981 ROW Management Plan provided for the use of herbicides only in limited situations, such as poison ivy complaints and treatment of cut stumps, but not for general vegetation management.

Thus, ROW management on Long Island had settled into a simple two-approach program. ROW property owned in fee by the utility, in residential areas, was maintained as turf grasses; while easements and more remote rights-of-way were brush hogged periodically. Herbicides were only used for bare ground weed control in substations, where there was greater security and little effect on the public at large. As time passed, the mowed areas of turf became more and more familiar to residents nearby, often generating complaints when the grass got too tall. Frequent mowing became more and more expensive. The remote areas would be clear soon after brush hogging, but in just a few seasons became crowded with stems of rapidly growing species, and mostly inaccessible to line and other crews. The program was beginning to become troublesome.

The early 1990's brought significant changes to ROW management on Long Island. First, LILCO integrated it's tree trimming and grounds maintenance divisions to form a Tree Trim/ROW Maintenance department, including dedicated transmission foresters. Soon afterward, these forestry personnel began to work with NY State Department of Public Service staff to bring the LILCO program more into conformity with other State utilities.

DPS staff was quick to note that LILCO's program depended to a great extent on expensive mowing treatments, and did not include selective ROW herbicide treatments which had been shown to provide cost effective brush management in NY State, while promoting species and habitat diversity. LILCO management was eager to improve ROW habitat, but was also hesitant to begin system-wide application of herbicides, especially within Long Island's pesticide-wary neighborhoods. A limited herbicide "test" program began in 1993 on a fairly remote section of ROW, which included basal, band, and foliar treatments to a formerly brush-hogged area. Materials tested included Tordon RTU (now Pathway), Garlon 4, Accord, and Spike. Results indicated that foliar treatments might be the most effective means of providing reliable brush control.

APPLYING IVM TO THE LIPA SERVICE TERRITORY

Integrated Vegetation Management

The concept of Integrated Vegetation Management (IVM) is derivative of the more general concept of Integrated Pest management (IPM), applied more specifically to the control of unwanted vegetation. Like its' more broadly defined parent, IVM involves the use of cultural, biological, physical, and chemical methods for reducing pest populations to tolerable levels.

IPM has been incorporated into agriculture, horticulture, and other management systems in an effort to address a variety of concerns. It was originally applied in recognition of problems, which developed both internally and externally to crop systems, such as pest resistance, pest resurgence, pollution, and effects upon non-target species. More recently though, IPM techniques have become important in addressing some of the social and legal concerns related to the use of pesticides. In NY State, for example, horticulturists who use "bio-rational" pesticides ("practically" nontoxic materials such as *Bacillus thuringiensis*, capsacin, and spray oil) for plant pest control are exempt from neighbor notification laws. Horticulturists who choose the bio-rational approach do so not only to avoid the time and expense of sending notification letters to neighbors, but also to avoid potential conflicts, which would result from such notifications. In this example, IPM assumes a role as part of a social and legal strategy, in addition to its' former practical and environmental roles.

Similarly, utilities must address social and legal concerns in addition to environmental ones, and the use of pesticides may raise concerns on the part of neighbors to the right-of-way. Land use adjacent to a right-of-way will most typically determine the degree of such concern. For example, the use of herbicides on a ROW, which runs only fifty feet behind hundreds of homes may cause considerable concern, be it warranted or not, whereas such treatments are barely noticed near agricultural or remote rights-of-way.

Urban electrical systems are for the most part under ground or built along city streets, so traditional ROW management is mostly unnecessary. Conversely, in rural or remote areas, there are many fewer neighbors to raise concerns about ROW management. In suburbs though, overhead rights-of-way often exist directly adjacent to people's back yards, and cross from street to street – not by choice of the utility, but typically resulting from development, which occurred subsequent to the establishment of formerly rural and remote rights-of-way. These people are utility customers, and therefore, stakeholders in the utility's ROW management program. Their concerns must be taken into account when addressing ROW maintenance in such communities.

Assessing the service territory for conversion to IVM

It was determined that, over a period of years, the ROW system should be converted to an IVM based program. Implementation of the IVM approach began with an assessment of the overall ROW situation throughout the Long Island service territory. The primary factors considered were ROW ownership, soil moisture conditions, and land use.

ROW ownership

Approximately two-thirds of the ROW acreage is owned in fee by the utility, including all of those areas, which had been planted in turf grasses in the 1960's. Because LILCO had made a de facto commitment to maintaining these turf grass areas, it was decided that the regular mowing program would be continued in the most visible areas, but scaled back to whatever extent possible. To avoid legal and public relations problems associated with herbicide use, it was decided to restrict herbicide use to fee-owned rights-of-way, projecting that about 700 acres would be converted to a selective herbicide program.

Although it is legal to do so, it was decided not to apply herbicides on easements, because of Long Island's general opposition to pesticides. Though it does cost more, mechanical treatment is opted for in such cases using infrequent mowing or brush hogging.

Soil moisture

Due to its glacial history, Long Island has widely varying regimes of soil moisture, ranging from highly productive loams to dry, infertile sands. The moister loam soils are generally found on the island's northern and western sections, and are naturally vegetated by mixed hardwood forests of Red Oak, Tuliptree, Red Maple, and other trees. Drier sandy soils to the south and east are dominated by Pine Barrens and associated Oak-Pitch Pine forest. Overall productivity, growth rate, and tree height vary accordingly. Adjacent forest trees reach to over 80′ on the loam soils, and only up to about 50′ in pine barrens.

Land use

Adjacent land use was considered to avoid methods that are generally incompatible with the surrounding neighborhood. For example, the use of herbicides very close to homes in densely populated areas was not chosen, even on fee-owned rights-of-way, opting rather to continue the grass mowing program. In agricultural and more remote areas with less public impact, a greater variety of programs could be selected.

ROW conversion

Beginning in 1994, ROWs were selected for conversion to the IVM approach as their treatment cycles came up. There were a number of conversion alternatives to be implemented, as follows.

Conversion of mowed grass ROWs

1. Frequently mowed grass to infrequently mowed grass and/or brush hogging program
2. Frequently mowed grass to selective herbicide program
3. Retain frequently mowed grass program

Conversion of brush hogged ROWs

1. Brush hogging to selective herbicides
2. Brush hogging to infrequent mowing
3. Retain brush hogging program

Some conversions, notably brush hogging to selective herbicides, required a two-step process. First, the ROW was brush hogged one final time to avoid spraying tall vegetation. The following year, re-sprouts were treated with the first herbicide application.

Applying the IVM concept

ROWs were classified according to the criteria of ownership, soil, and land use as described above; in order to determine the IVM program that would be applied to them. The specific actions needed to accomplish the conversion were then implemented as these rights-of-way became due for treatment. Details of program selection and conversion and for each ROW situation are as follows...

Ownership: Fee owned
Soil: Dry to Moist
Land Use: Medium to High Density Residential
Program Selected: Regular (Frequent) Mowing
560 Total Acres

Crews use grass mowing tractors with 72″ cut width, backed up by a helper to trim around guard rails, poles, and towers.

These rights-of-way were formerly being mowed, so no methodological conversion was involved. However, in an effort to reduce overall cost, mowing frequency was cut back from four or five per year to two or three mowings. Some ROWs with two mowings are additionally "touched up" by trimming the street crossings only. Cutting back on frequency initially led to numerous high grass complaints, but complaints have declined considerably after discussions with customers.

Ownership: Fee owned, Easement
Soil: Moist
Land Use: Low Density Residential, Agricultural
Program Selected: Infrequent Mowing
240 Total Acres

These ROWs were converted from both frequent mowing and brush hogging programs, to a program of mowing every one to three years with heavy-duty 4WD tractors with 72″ brush hog decks. Many sections of ROWs, which were formerly mowed frequently, were far enough from homes to justify this conversion. By mowing only once a year, they have been converted to a meadow-like condition with a greater variety of non-grass species and low growing shrubs. On moist soils, brush hogging results in an open ROW for only one or two years before vegetation again overtakes the ROW, and for a few more years the ROW contains significant vegetation until the next cycle. After 2 years though, this vegetation is still mowable using 4WD tractor/mowers. Instead of opting for more expensive brush hogs every four or five years, the use of less expensive tractors, but more frequently keeps the ROW much clearer at all times.

Ownership: Fee owned, Easement
Soil: Dry
Land Use: Remote, Agricultural
Program Selected: Periodic Brush Hogging
710 Total Acres

On dry, sandy soils characteristic of Long Island's east end, re-growth is naturally slowed by environmental limitations. The dominant tall tree species on these ROWs is pitch pine associated with under story shrubs, such as scrub oak, various heath shrubs and groundcovers. Our experience shows that if cut properly, these ROWs can remain open for eight years and more. The key seems to be mowing height. By cutting no closer than 6" from the ground, the pines are significantly set back, yet surrounding shrubs recover quickly and overtop them. Thus, shading from surrounding shrubs controls the taller pines. Pitch pine germinates best on open sandy areas that are free from competition, so this method also reduces seedbed availability by avoiding soil disturbance.

Ownership: Fee owned
Soil: Moist
Land Use: Remote, Agricultural
Program Selected: Selective Herbicides
700 Total Acres

On loam soils which hold significant moisture, regrowth after mowing is rapid and, unless mowed again it will soon block ready access to ROW facilities. The most effective way to control such vegetation is through the use of selectively applied herbicides, however, along with this method come various legal and public relations problems as described earlier in this paper. LIPA believes that applying herbicides on easements will be objected to by enough Long Island property owners as to cause significant negative repercussion. LIPA has chosen to apply herbicides only where the ROW is fee-owned, using primarily low volume foliar treatments. This way, the cost and environmental benefits of herbicides are gained on a significant portion of the ROW acreage, without imposing it's (perceived) risks upon the public at large.

Ownership: Fee owned, Easement
Soil: All
Land Use: Commercial, Agricultural, Recreational
Program Selected: Mixed Use
200 Total Acres

LIPA is always ready to consider requests to use ROW property for compatible uses. Some compatible uses of LIPA ROW property include farms, nurseries, Christmas tree farms, bicycle paths, and parking lots. The tenant usually pays a reasonable fee, and LIPA no longer has to maintain the vegetation, resulting in a win/win situation for all parties.

SUMMARY

The LIPA service territory is of highly variable geography and demography, which greatly influence ROW management decisions. These decisions are mostly influenced by three criteria: ROW ownership, soil moisture conditions, and adjacent land use.

Integrated Vegetation Management (IVM) provides the forester with a range of techniques to manage ROW vegetation that can accommodate the varying interests of stakeholders along the ROW. By evaluating soil conditions, property ownership, and land use, LIPA selects and deploys various IVM methods. This broad-based IVM approach strives to balance cost with legal considerations, public acceptance, and environmental impacts.

BIOGRAPHICAL SKETCH

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The Implementation of Vegetation Management Projects on U.S. Forest Service Lands: The Big Eddy-Ostrander Vegetation Project on the Mt. Hood National Forest

William T. Erickson

Utility forestry has become a primary maintenance issue for the Bonneville Power Administration (BPA) since the August 10th, 1996, western United States outage. This issue has been sustained by the massive power outage caused by tree outages last summer (2003) in the northeastern United States. One of the responses to the 1996 event by the Bonneville Power Administration was to develop a programmatic Environmental Impact Statement (EIS) for the transmission system. The goal of the EIS was to develop a strategy and provide a clear path for managers to implement environmental analysis when developing powerline vegetation management programs on BPA rights-of-way that cross in the Pacific Northwest. The Big Eddy-Ostrander project initiated on U.S. Forest Service lands, proposed the use of herbicides using the EIS as the analysis guide. As a cooperative project with the Oregon Department of Agriculture and the U.S. Forest Service to control noxious weeds, many items needed to be worked out. These items included: the determination of who was the lead agency for the project, what formats should be used for environmental documents, who could appeal the process, and what did each agency want to see during the environmental analysis process. The end result of the process was that in the summer of 2003, BPA made the first herbicide treatment for vegetation management on the right-of way located in the Zig Zag Ranger District in over 20 years.

Keywords: Vegetation management, federal lands, National Environmental Protection Act, biological evaluations, ROW

INTRODUCTION

The Bonneville Power Administration (BPA) finalized and published the Transmission System Vegetation Management Program Environmental Impact Statement (BPA EIS) in May 2000. One of the many goals of the EIS was to develop a strategy and provide a clear path for managers to implement environmental analysis when developing powerline vegetation management programs on rights-of-way (ROW) that cross all lands in BPA's Pacific Northwest service area. Specifically, on federal lands in the system that compose over a third of the lands in which BPA has transmission line corridors.

These vegetative management goals include:

- improvement of efficiency and consistency of environmental documentation and protection,
- emphasis on Integrated Vegetation Management (IVM) and the development of low growing plant communities,
- foster working relationships with land-managing agencies and Native American Tribes in the BPA operational region,
- the need to update our program and develop an appropriate approach to vegetation management, and
- the development of an approach that scientifically supports Integrated Vegetation Management and protects all resources encountered on the right-of-way.

One of the first projects chosen to be developed on U.S. Forest Service lands that proposed the integration

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

Fig. 1. Mt. Hood looking west from The Dalles Dam, Oregon. 145 km (90 miles) east of Portland, Oregon.

and use of herbicides in National Forest lands using the new BPA EIS was a 119 hectare (295 acre) section of right-of-way in the Mt. Hood National Forest located 72 km (45 miles) east of Portland, Oregon. The 8.85 km (5.5 miles) section of right-of-way had been managed for at least 20 years using only hand cutting methods.

Once the decision was made to proceed with this project, it naturally evolved into three main phases:

- the first phase is the pre-analysis phase where the agencies decide what their goals are, how the various tasks and responsibilities will be divided, and who is responsible for the project funding and decisions,
- the second phase is the analysis itself and developing the field work and appropriate environmental clearance documents needed to perform the project,
- the final phase is the implementation of the planned vegetation management project.

PHASE 1: PRE-ANALYSIS

One initiating factor for BPA to become involved in this site was the Oregon Department of Agriculture (ODA) and the Zig Zag Ranger District's need to control noxious weeds in the BPA corridor. These agencies came to BPA to see if our approach would help them develop the environmental analysis needed to apply the herbicide methods needed to facilitate control of these problem weeds.

Over the past 15 to 20 years, the right-of-way had become infested with noxious weeds. A noxious weed of concern to the ODA was the infestation of the ROW with yellow and orange hawkweeds which are class "A" listed noxious weeds in the state of Oregon. This BPA ROW currently is one of three sites in the State of Oregon where orange and yellow hawkweeds occur.

BPA transmission line corridor needs are: the control of tall growing trees, the removal of vegetation from access roads and tower structures, and the removal of off right-of-way danger trees that can fall into the lines.

Since the early 1980s the ROW vegetation had been managed without the use of herbicides by only hand cutting and mechanical methods because of a court injunction on all National Forest lands in the Pacific Northwest Region of the U.S. Forest Service. Region 6 of the U.S. Forest Service responded to this injunction by developing the Final Environmental Impact Statement for Managing Competitive Vegetation (USDA FS, 1988) and presented it to the Court. The plaintiffs had additional concerns so the case went to mediation. From the mediation process, additional requirements were placed into the planning process and the list of available herbicides was greatly narrowed. These requirements had to be incorporated into the planning process.

The site

The project site is located in the Big Eddy-Ostrander transmission line corridor that crosses the Cascade Mountains north of Mount Hood, 72 km (45 miles) east of Portland, Oregon.

The ROW width ranges from 137 m (450 feet) to 168 m (550 feet) and is 8.85 km (5.5 miles) long. Elevation ranges from 600 m (1960 ft.) at the western end to 1050 m elevation (3440 feet) at the eastern summit of Lolo Pass.

The vegetation consists of tall growing conifer species: Pacific silver fir (*Abies amabilis*), noble fir (*Abies*

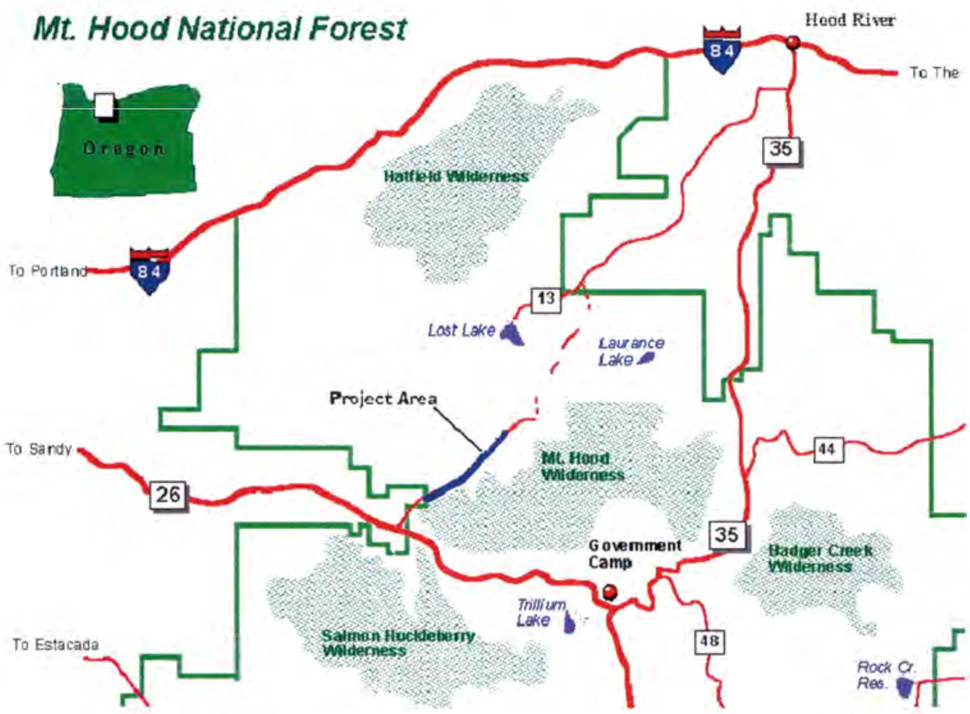

Fig. 2. Project Location Mt. Hood National Forest, http://www.fs.fed.us/r6/mthood/maps/vicinity-map.

procera), grand fir (*Abies grandis*), mountain hemlock (*Tsuga mertensiana*), western hemlock (*Tsuga heterophylla*) and Douglas fir (*Pseudotsuga menziesii*). Tall growing re-sprouting hardwood species on the site include: red alder (*Alnus rubra*), big leaf maple (*Acer macrophyllum*), Rocky Mountain maple (*Acer glabrum douglasii*), and bitter cherry (*Prunus emarginata*) (BPA EIS, 2000; Dent, 1956).

Noxious weeds are also present on the corridor. A field survey in May of 2002 revealed that 20.2 hectares (50 acres) of the ROW corridor were infested with noxious weeds. The main weeds of concern are orange hawkweed (*Hieracium aurantiacum*) and yellow hawkweed (*Hieracium floribundum*) that are "A" listed weeds in the state of Oregon. The ODA had requested that the Ranger District start an aggressive program to control these hawkweed species. In addition, other noxious weeds such as scotch broom (*Cytisus scopartus*), tansy ragwort (*Tanacetum spp.*), and diffuse knapweed (*Centaurea diffusa*) have also infested the site (CH2M Hill, 2002). The presence of these non-native species encroaches on the native plants in the ROW and reduces the plant diversity of the site. As federal agencies, BPA and the U.S. Forest Service are required to control weeds as required under the 1990 amendment to the Noxious Weed Act (7 USC 2801-2814) (CH2M Hill, 2002).

Agency coordination

Before the process could begin, all of the goals and objectives had to be identified. Not only was there a need to identify resource objectives but there was a need to develop process objectives as well. Since it was a new process for both BPA and the U.S. Forest Service, many issues needed to be worked out. These issues included:

- the determination of who was the lead agency for the project,
- what formats should be used for environmental documents,
- what types of analysis needed to be done,
- whose process applied,
- what decisions needed to be made, and
- what each agency wanted to see during the environmental analysis process.

Resolution of planning issues

On June 26, 2001, BPA had an interagency meeting to discuss the hawkweed infestation on the Mt. Hood National Forest and under a BPA powerline corridor. The participants included representatives from BPA, the U.S. Forest Service from the Zig Zag Ranger District, Supervisory office and the Region 6 office, and the Oregon Department of Agriculture. This population of hawkweed is one of three populations in the entire State of Oregon and is a significant concern for ODA (Hollen, 2001).

At the meeting the following agreements, decisions, and goals were established:

- the objective of the treatments is to substantially control noxious weed infestations on the ROW using all available methods (manual treatments & herbicide treatments). The emphasis will be to contain and reduce the infestation of noxious weed species on the ROW corridor and the associated access roads.
- BPA later added its objective and need to control vegetation that would become a hazard to the powerline or interfere with maintenance to the project

Fig. 3. Yellow hawkweed (*Hieracium floribundum*) (ODA Picture).

as a cost effective way of addressing the total issues of vegetation management of the powerline corridor instead of doing two analyses, one for noxious weeds and another for powerline reliability. The objectives of both programs were included in this analysis project since much of the treatment would be the same for both issues. Another plus to combining the issues was to determine the goals and objectives for the long-term by identifying and including any potential future treatments that may be needed to address the vegetation management needs on the site.

- BPA will be the lead National Environmental Protection Act (NEPA) planning agency, and the Forest Service will be the lead implementation agency. *It was later determined that BPA would be the lead implementation agency since the BPA Vegetation Management EIS specifically addresses BPA actions and not the U.S. Forest Service's.* ODA will provide technical support in treatment methods, and monitoring effectiveness of treatments.

In later meetings, it was determined that BPA would be the decision making agency and the Forest Supervisor would review our findings as to compliance with the Mt. Hood National Forest Plan, U.S. Forest Service Manual Direction, The Northwest Forest Plan, the U.S. Forest Service Region 6 FEIS for Managing Competing and Unwanted Vegetation, and specifically the BPA Transmission System Vegetation Management EIS in which the U.S. Forest Service is a cooperating agency (Larson, 2003).

- U.S. Forest Service will provide BPA with maps of the infested areas that are associated with the powerline corridors.
- U.S. Forest Service will do initial project scoping with their resource specialists to identify any known issues or concerns.
- BPA will provide a GIS layer with the corridor locations and the tower locations.
- BPA will initiate a site specific Supplement Analysis using the checklist process identified in the *2000 BPA Transmission System Vegetation Management EIS*.
- ESA consultation will be coordinated jointly between the U.S. Forest Service and BPA using the level 1 team process of the U.S. Forest Service.
- BPA will provide the U.S. Forest Service with emergency contacts for fire response planning; this will include the 24 hr dispatch office and the line maintenance foreman for the various areas.

PHASE 2: ANALYSIS PHASE[1]

Initial planning

After the project was proposed BPA started a field review to assemble the project goals, the identification of issues, and the specific needs of the site to start the drafting of the BPA Checklist developed to document the information needed for the Supplement Analysis (SA) document that is tiered to the BPA EIS.

1 From: (Erickson and Mader, 2002).

One of the biggest steps of the process is to identify the significant resource issues that may be encountered and then identify the vegetation methods that could be used on the site. With a set of specific prescriptions and mitigation methods that apply to the various resources on the ROW, a Biological Evaluation (BE) can be developed based on those planned actions, which assess the impact of those prescriptions and methods.

After a review of the right-of-way, BPA identified six main resource issues that needed to be addressed. These areas were identified and mapped for management purposes. These resource issues were:
- Riparian areas and wetland: 27.9 hectares (69 acres).
- Areas where anadromous fish may be an issue: 43.7 hectares (108 acres).
- Steep slopes: 32.0 hectares (79 acres).
- Spanned Canyons: 4.1 hectares (10 acres).
- Areas near Critical Spotted owl habitat.
- Areas where no issues occur: 11.7 hectares (29 acres).

Once the resources are identified then methods and mitigations can be identified from the BPA EIS that would result in a "no affect" determination in the BE analysis.

Specific resource prescriptions based on the programmatic EIS

With the identification of the resources on the ROW, specific treatment and alternative can be identified based on the programmatic BPA EIS. The vegetation manager can identify the methods, treatments, and herbicides that when applied individually or in combinations meet the management goals of the project and protect the resources identified. The following statements are the prescriptions for the Big Eddy-Ostrander project:

Riparian areas and wetlands

Definition: U.S. Forest Service lands within 30.4 m (100 ft.) of a stream or wetland. All manual, spot and localized herbicide, and biological treatments. No mechanical treatments within 15.2 m (50 ft.) of streams or wetlands.
- Manual: Hand tools and chainsaws.
- Mechanical: None within 15.2 m (50 ft.) of streams or wetlands, only on access roads and tower sites.
- Herbicide: Only non-toxic formulations and slightly toxic (to aquatic species) formulations of glyphosate (such as Rodeo®), dicamba (Trooper/Vanquish), and triclopyr (Garlon 3A and Garlon 4) may be prescribed for wick, cut-stump, basal-stem, stem-injection, and spot-foliar treatments (localized). Broadcast treatment (handgun only) can be completed with the appropriate buffers on noxious weeds, access roads and tower sites. Spray application would be prohibited when wind speeds are greater than 8 kph (5 mph).

Buffers:
- Non-toxic and slightly toxic formulations of glyphosate and triclopyr (Garlon 3A) may be used to the water's edge when using spot and localized treatments.
- Garlon 4 may be used when more than 10.6 m (35 ft.) from streams and on seasonally dry wetlands.
- The buffers for dicamba and picloram are 7.6 m (25 ft.) for spot treatment and 10.6 m (35 ft.) for localized treatments.
- Broadcast treatment buffers will be 10.6 m (35 ft.) for approved formulations of glyphosate, and tryclopyr TEA (Garlon 3A).
- Broadcast treatments for tryclopyr BEE (Garlon 4), picloram (Tordon 22k) and dicamba (Trooper or Vanquish) buffers will be 30.4 m (100 ft.).
- At the discretion of the applicator, a 7.6 m (25 ft.) no-spray buffer may be used if one of the following conditions applies: (1) recommended by Mt. Hood NF, Zigzag Ranger District, Fisheries Biologist for a particular water body, or (2) variable weather conditions exist that may cause drift uncertainty. The option of a contingency buffer is provided because little empirical toxicity data are available for aquatic organisms under field applications. However, available toxicological literature has failed to find toxic effects on aquatic organisms when applied at the approved application rates.

Vegetation cut within a riparian area shall be treated as follows:
- Larger diameter trees greater than 25.4 cm (10 inches) in Diameter at Breast Height (DBH) felled within riparian areas will be felled across (i.e. to span) the stream. However, in no case should more than a total of 3–4 trees be felled across the stream per 30.4 m (100 ft.) of right of way. This number includes existing fallen trees that are in the stream.
- Other trees that need to be felled should be felled uphill and/or parallel to the stream or water body.
- A minimum of 6.1 m (20 ft.) wide gaps through this down material are required every 30.4 m (100 ft.) of the stream in order to provide for wildlife access.
- Slash piles shall not be located within 15.2 m (50 ft.) slope distance of the stream.
- No trees shall be felled across stream course in any area where there is obvious stream instability.

Areas where anadromous fish may be an issue[2]

Definition: U.S. Forest Service lands within 122 m (400 ft.) of a listed stream. All manual, spot and lo-

2 The buffers set for this project were based on an effort to minimize the amount of analysis to make a "no affect" determination for anadromous fish species. At the time of the analysis, BPA planners were to consider the issue when planned projects were within 122 m (400 ft.) of listed Threatened and Endangered (T&E) fish streams. Since the time of the analysis for the BE for the project, the Environmental Protection Agency has been in consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service due to court cases (Washington Toxic Coalition v. EPA) in the Region that are resulting in effect determinations on specific herbicides used

calized herbicide, broadcast treatments with handgun only on access roads and tower sites, and biological treatments. No mechanical treatments within 30.4 m (100 ft.) of stream.

- Manual: Hand tools and chainsaws.
- Mechanical: None within 30.4 m (100 ft.) of stream. Only on access roads and tower sites.
- Herbicide: No herbicides within 30.4 m (100 ft.) from the waters edge (which in this case the "sensitive stream" is at least 30.4 m (100 ft.) from the right-of-way). From 30.4 m (100 ft.) to 122 m (400 ft.) away from water, use only non-toxic formulations or slightly toxic (to aquatic species). Aquatic formulations of glyphosate, dicamba (Trooper/Vanquish), and triclopyr (Garlon 3A only) may be prescribed for wick, cut-stump, basal-stem, stem-injection, and spot-foliar treatments (localized). Broadcast treatments with handgun only on access roads and tower sites.
- Highly toxic and very highly toxic (to fish) herbicides will not be used within 122 m (400 ft.) of a Threatened and Endangered (T&E) fish stream.

Steep slopes

Definition: U.S. Forest Service lands where a steep slope precludes the use of mechanical treatments. Mechanical treatments are limited to roads and structure sites.

- Manual: Hand tools and chainsaws.
- Mechanical: Only on access roads and tower sites.
- Herbicide: glyphosate, picloram (Tordon 22K), triclopyr (Garlon 3A and Garlon 4), and dicamba (Trooper or Vanquish) may be prescribed for wick, cut-stump, stem-injection, basal-stem, spot-foliar, or broadcast foliar treatments. Do not apply granular herbicide when slope exceeds 10% slope.

Spanned canyons areas

Definition: Any areas in the corridor with greater than 38.1 m (125 ft.) vertical distance between the ground surface and transmission lines. Here, removal is periodically required only of individual trees (single tree cuts) that could encroach into the transmission corridor danger zone.

- Manual: Hand tools and chainsaws. Refer to riparian treatment specifications.
- Mechanical: Only on access roads and tower sites.
- Herbicide: For the treatment of noxious weeds only. Refer to riparian treatment specifications.

Areas next to spanned canyons with line to ground clearance between 22.8 m (75 ft.) and 38.1 m (125 ft.):

- All conifers over 4.27 m (14 ft.) tall will be controlled. Conifers over 7.6 m (25 ft.) tall will be cut for clearance.
- Hardwood trees over 9.1 m (30 ft.) tall will be cut for clearance and treated.
- Hardwood trees less than 9.1 m (30 ft.) tall will be left untreated.

Areas near critical spotted owl habitat (overlaps 1.6 km (1st mile) of project) towers (39/6 to 40/2)

- Where opportunity exists, suspend vegetation management activities within 0.4 km (0.25 mi.) of spotted owl critical habitat between March 1 and June 30, unless the owls are shown not to be nesting.
- For future entries, examine any large danger trees 28 cm (11 in.) diameter at breast height (DBH) that need to be removed in spotted-owl habitat for evidence of owls. If a tree has evidence of owl nesting activity, conduct formal consultation with the U.S. Fish and Wildlife Service.
- In case of an emergency danger tree removal—a tree suddenly becoming an imminent threat to the line posing a danger to life and property—immediately examine the felled tree for evidence of owl nesting. If such evidence is found, start emergency consultation with the Fish and Wildlife Service; or, if the situation occurs during off-duty hours, conduct after-the-fact emergency consultation the next business day.

Areas where no issues occur

Definition: U.S. Forest Service administered lands, including Late Successional Reserve (LSR), with no other environmental constraints. All manual, mechanical, biological, and herbicidal treatments.

Herbicides: glyphosate, picloram, triclopyr (Garlon 3A and Garlon 4), and dicamba may be prescribed for wick, cut-stump, stem-injection, spot foliar, broadcast foliar, cut stubble, and basal-stem treatments.

Getting help with the Biological Evaluation

Since the Project was on Mt. Hood National Forest Lands, one of the biggest tasks of this analysis project was the development of a Biological Evaluation (BE) for the proposed action. A BE is required for any U.S. Forest Service management activity that may alter the habitat or affect individuals or populations of "Threatened, Endangered or Sensitive" species (TES). The BE process documents activities necessary to make sure a proposed project will not affect the continued existence or cause an adverse effect on:

- TES species that are listed or proposed to be listed as endangered or threatened by the U.S. Fish and Wildlife Service or National Marine Fisheries Service,
- species listed as sensitive by the U.S. Forest Service Region 6.

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in the Pacific Northwest. At the time of this paper, this consultation with EPA is resulting in buffers that are similar to the BPA's established buffers as published in the BPA EIS. The BPA EIS buffers are based on Electric Power Research Institute, Report No. TR-113160 (Goodrich-Mahoney, 1999).

Fortunately BPA had previously completed a BE for the project area for the vegetation management of tall growing trees in 2000 (Shapiro and Associates, 2000). Since only hand-cutting methods were evaluated, an update of the BE would need to be completed with herbicide methods included in the analysis. With the inclusion of herbicide as an alternative, more issues had to be addressed for TES species. To do those BPA developed a contract with CH2M Hill to coordinate, develop, and write the BE and any environmental documents needed for this project (CH2M Hill, 2002). On December 11, 2002, BPA awarded a service contract to CH2M Hill to complete this work. The Project Manager for CH2M Hill was Steven Mader, Ph.D., Environmental Specialist for the company. Through his staff and contacts with the U.S. Forest Service he assembled the site specific information for the project, assessed the affects, developed a template for the SA, and wrote the Biological Evaluation for the planned action.

Tiering site specific analysis to the EIS

The purpose of BPA developing the Transmission System Vegetation Management Program EIS (BPA EIS) was to increase efficiency and constancy throughout the BPA service area. Before developing the EIS, BPA had to look at each project and identify the specific issues and make decisions on an individual basis. When BPA developed these analyses on an individual basis, consistency and timeliness became a significant issue. This became apparent when BPA proposed vegetation projects on lands managed by other Federal agencies. The development of an EIS with the cooperation of these agencies would help streamline project analysis by establishing a procedure, which outlines basic planning steps and mitigation measures and then tiering them to site-specific situations. The BPA EIS also identified and addressed many of the common environmental issues, which may occur on BPA rights-of-way when performing vegetation management.

This tiering process to a site specific project is accomplished by four main phases. These phases are:

1. using the planning steps established in the BPA EIS to make sure all potential issues are considered,
2. reviewing the BPA EIS to make sure all impacts have been considered,
3. applying the appropriate established mitigation measure to ensure environmental protection,
4. developing a Supplemental Analysis (SA) summary to document the site specific analysis and its consistency with the BPA EIS. If the results are not consistent, then additional environmental analysis is required. For projects on Federal lands the SA would incorporate those agencies' policies and procedures for implementing NEPA.

Table 1. BPA EIS planning steps

Step #	Planning step
1.	*Identify* what vegetation needs control
2.	*Identify* natural resources present
3.	*Identify* land use and owner/manager
4.	*Determine* what method to use
5.	*Determine* how to dispose of debris and revegetate, if necessary
6.	*Determine* if monitoring is needed
7.	*Prepare* environmental documentation

As identified in the Big Eddy-Ostrander vegetation management checklist, the site-specific planning steps are as follows (CH2M Hill 2002)[3]

Identify facility and the vegetation management need

Description of the Proposed Action- BPA proposes to clear unwanted vegetation in the rights-of-way and around tower structures that may impede the operation and maintenance of the subject transmission line. Also, access road clearing will be conducted. All work will be in accordance with the National Electrical Safety Code and BPA standards. BPA plans to conduct vegetation control with the goal of removing tall growing vegetation that currently is or will soon be a hazard to the transmission line. BPA's overall goal is to have low-growing plant communities along the rights-of-way to control the development of potentially threatening vegetation. All hardwood tree species over 30.4 cm (1 ft.) tall and all conifers over 3.66 m (12 ft.) tall need to be controlled.

In addition, listed noxious weeds are present in the ROW. A cooperative effort to control noxious weeds is also proposed. The main weeds of concern, the hawkweeds, are "A" list weeds in the State of Oregon. In addition tansy ragwort, scotch broom and knapweed have been a concern. These weeds and other listed noxious weeds are non-native species that need to be controlled to prevent any additional spread of these weeds and encroachment of habitat for native species on the right-of-way. These noxious weed species will be controlled using an Integrated Vegetation Management Approach (IVM) using a combination of manual, mechanical herbicides, and biological methods.

The site is a Christmas Tree Permit area. Current treatments allow for all conifer species to be left uncut until they reach a height of 3.66 m (12 ft.). Conifer trees over 12 feet tall will be cut as specified.

The width of the ROW easement varies from 137 m (450 feet) to 168 m (550 feet). All work will be accomplished by selective vegetation control methods (except for access roads and tower sites) to assure that there is little potential harm to non-target vegetation and to low-growing plants. The work will provide system reliability.

Initial entry

Brush management on the ROW work will be to clear tall growing vegetation that currently is or will soon

3 From the "Supplement Analysis" (Hutchinson and Mader, 2002) to illustrate how the BPA EIS planning steps are used to summarize the information in the Biological Evaluation and "checklist" for the Big Eddy-Ostrander vegetation management analysis project.

pose a hazard to the lines; treat the associated stumps and re-sprouts with herbicides (spot and localized treatments) to ensure that the roots are killed preventing new sprouts and selectively eliminating tall growing vegetation before it reaches a height or density to begin competing with low-growing vegetation. Areas may be replanted or reseeded with low-growing vegetation if there is limited vegetation to re-establish the site. Desirable low-growing plants will not be disturbed on the right-of-way by using selective control methods, and by keeping trucks and equipment on designated access roads and trails. All work will take place in existing rights-of-way. Slash and debris will be loped and scattered.

Access roads and tower sites will be treated using selective and non-selective methods that include, hand cutting, mowing, and herbicide spot, localized, and broadcast applications including cut stubble and localized granular treatments.

Noxious Weeds- The selection of methods and herbicides for noxious weed management will be based on their location and proximity to water resources. Treatment will be limited to spot, localized and ground broadcast treatments, non-selective treatments using ground broadcast treatment may be required in areas of high infestation of weeds on the ROW (42/3 to 43/1), access roads and tower sites. Localized granular treatments will also be considered.

Subsequent entry

Danger trees are trees located off of the right-of-way, are potentially unstable, and will fall within the minimum distance of the conductor. Trees that are an imminent hazard (emergency) will be removed when identified. The danger tree process requires a survey of the trees by a specialized BPA crew that identifies hazard trees along the ROW, marks them, appraises the trees, and negotiates with the landowner on the details of the hazard tree. The tree remains the property of the landowners after cutting.

The vegetation management program will be designed to provide a 3–8 year maintenance free interval. The overall vegetation management scheme will be to initially clear and remove all tall growing trees using a combination of manual, mechanical, and herbicide treatments, as outlined in the initial treatment.

Future cycles

Future cycles of work will involve cut stump, basal treatments, or tree cutting. During routine patrols, the ROW will be examined for edge and danger trees with appropriate actions taken.

Identify surrounding land use and landowners/managers

The project area is entirely within property managed by the Zig Zag District of the Mt. Hood National Forest. The ROW has a paved road over the entire length of the treatment area. The public accesses the area for recreation. Portions of the project area are designated as a Christmas Tree Permit Area. It is estimated that 2,000 to over 3,000 or more permits are issued in this area for tree cutting by the public. The surrounding areas consist of Matrix forest lands with "Riparian Reserve" overlays.

The U.S. Forest Service performed initial project scoping with their resource specialists to identify known issues or concerns. Public involvement has been requested through: (1) tribal notification; (2) U.S. Forest Service newsletters describing the proposed project and offering a BPA contact for questions and comments; and (3) notification of adjacent landowners.

The U.S. Forest Service notified the public about the proposed work through its quarterly newsletter called "Sprouts" in the spring, 2002 edition, but no questions or comments were received from the general public. The U.S. Forest Service determined that the proposed work would be consistent with regulations governing the use and occupancy of the National Forest System lands.

BPA prepared a Biological Evaluation in July 2000, which was reviewed by the U.S. Forest Service (USDA 2001), and amended in July 2002 (CH2M Hill, 2002). The U.S. Forest Service worked cooperatively with BPA in preparation of this BE and other environmental documentation. ESA consultation would be coordinated jointly between the BPA and U.S. Forest Service using their Level 1 team process.

For line segment 44/5 + 313 feet to 39/3, herbicide-treated areas would be posted with re-entry intervals 7 days before and 30 days after treatment.

Identify natural resources

The project area is bisected by several ephemeral and seasonal drainages and is adjacent to the Clear Fork and Sandy Rivers, both of which contain resident and anadromous fish populations. The project area itself has been maintained as rights-of-way for many years and supports an artificially maintained, variable composition, early serial stage vegetation community. Some areas, generally those adjacent to stream channels and valleys, support older vegetation communities because the transmission line over them is sufficiently high so that regular vegetation control was not warranted.

Special Status Species: No federally listed or proposed threatened or endangered species are known to occur in the project area; however, several listed fish species do occur in the general vicinity. In addition, several U.S. Forest Service Region 6 Sensitive species may occur in the project area or its vicinity. A Biological Evaluation (BE) for special status fish and wildlife species has been prepared for and accepted by the U.S. Forest Service (Biological Evaluation Addendum for the Big Eddy-Ostrander Transmission Corridor; CH2M Hill, 2002). The U.S. Forest Service prepared the Proposed, Endangered, Threatened, and Sensitive Plant Biological Evaluation.

Survey and Manage Species: The Record of Decision and Standards and Guidelines for Amendments to Survey and Manage species, Protection Buffers, and other Mitigation Measures Standards and Guidelines, January 2001, amends the Northwest Forest Plan. Species in Categories A and C require a survey be completed prior to habitat-disturbing activities.

A field reconnaissance was conducted within the project area for vascular and non-vascular plants on June 27, 2000. No Survey and Manage species were located. The proposed project would therefore have no effect on these species and no mitigation on project design is recommended.

It was determined from a literature review, aerial photos, and field knowledge that no known habitat for Survey and Manage Terrestrial and Aquatic Species occur within the proposed project area, since the area does not offer habitat. The proposed project would therefore have no effect on these species and no mitigation on project design is recommended.

Cultural Resources: No cultural resources are known to occur within the project area. Soil excavation or soil disturbing activities, if any, would be limited to access roads and tower sites using mechanical equipment, and would not exceed 6 inches in depth below the soil surface.

Environmental Land Audit: An environmental land audit to identify the presence of hazardous and toxic wastes was not performed for this project because the project does not involve major ground disturbance.

Permit Information: No permits are necessary for this project as proposed.

Determine vegetation control and debris disposal methods

Vegetation control methods include manual cutting of tall-growing vegetation, mechanical cutting (mowing) of tower areas and access roads, and herbicide treatment of noxious weeds using spot, localized and broadcast herbicide applications. Herbicide treatments would involve glyphosate, picloram, triclopyr (Garlon 3A and Garlon 4), and dicamba. Spot applications include stump treatments, injection and notch treatments, and wick and carpet roller applications. Localized applications include basal treatment, low-volume foliar treatment, and granular application. Broadcast ground applications, include high-volume foliar and cut-stubble treatments.

No existing vegetation that could provide shade, stream bank stability, or large woody debris to streams occupied by anadromous fish would be removed. Otherwise, slash and debris would be lopped and scattered.

Determine revegetation methods if necessary

Areas would be replanted or reseeded with low-growing species when there are no existing low-growing species, or if there is a low potential for natural revegetation by low-growing species and a high potential for natural revegetation by tall-growing species to reinvade the site. Seeding would be completed when sufficient moisture exists to allow for two months of vegetative growth. Seeding could be completed any time of the year, except during the hot summer months.

Determine monitoring needs

A BPA inspector would monitor work being performed. The Oregon Department of Agriculture has agreed to provide effectiveness monitoring. BPA would provide the USFS with Emergency Contacts for Fire Response Planning, which would include the 24-hour Dispatch Office and the Line Maintenance Foreman for the various areas. In addition, routine ground and aerial patrol would be performed by BPA.

Prepare appropriate environmental documentation

Potential Project Work or Project Impacts that are Different than those Disclosed in the Transmission System Vegetation Management Program EIS: The vegetation management methods and techniques that would occur during this project (manual cutting, mechanical cutting, and herbicides) are all addressed in the Transmission System Vegetation Management Program EIS. All of the potential project impacts (habitat modification, herbicide toxicity, adjuvant toxicity, soil erosion) have been disclosed previously in the FEIS.[4] Strong mitigation measures from the FEIS and protective buffers would be applied to lessen potential impacts.

How Differences in Impacts Affect Natural Resources: There are no impacts expected from the proposed project work that were not disclosed previously in the FEIS. Therefore, no substantial differences in effects of natural resources expected between those described in the BPA EIS and those expected from the proposed project. Findings: The project generally is consistent with the Northwest Power Planning Council's Fish and Wildlife Program, as well as BPA's Transmission System Vegetation Management Program EIS (DOE/EIS-0285), Record of Decision (ROD), and supplemental ROD. This Supplement Analysis finds that: (1) implementing the proposed action would not result in any substantial changes to the Transmission System Vegetation Management Program that are relevant to environmental concerns; and (2) there are no significant new circumstances or information relevant to environmental concerns and bearing on the Transmission System Vegetation Management Program or its impacts. This Supplement Analysis is tiered to the program-wide FEIS and ROD; therefore, no further NEPA documentation is required (Hutchinson and Mader, 2002).

With the BE and Supplement Analysis document finished on December 12, 2003, it was forwarded to the Mt. Hood National Forest staff for review.

4 USDA Forest Service, 1988.

USFS concurrence

Once the environmental documents had been completed, they were referred to the Mt. Hood Forest Supervisor's office for review. Since a lot of time had passed from the initial meeting and the review of the final draft of the documents, the Forest Service had a chance to review their own process and how other agencies' processes such as BPA's would comply with their documentation needs.

One positive outcome of this assessment was that so long as BPA was the Lead agency for this federal action, BPA could use its own process and procedure to finalize the NEPA documentation required and make the decision based on our own established agency methods. To facilitate this action properly, the Forest Service requested that all references to any decisions and action or joint decision by the U.S. Forest Service be deleted. By stating that BPA was the sole lead of the project and the Forest Services role was that of a concurring party, BPA was able to use its own process for establishing and completing NEPA for the project.

This meant that BPA was not subject to the Forest Service's "Administrative Appeal Process" rules since the U.S. Forest Service was not making any decision on the action. Their role for the final process was to review our documents and make sure our actions concurred with the Mt. Hood National Forest Plan, Forest Service Manual Direction, The Northwest Forest Plan, the U.S. Forest Service Region 6 FEIS for Managing Competing and Unwanted Vegetation, and specifically the BPA Transmission System Vegetation Management EIS as a cooperating agency. This letter of concurrence was issued on March 27, 2003 (Larson, 2003). With this concurrence letter, BPA was able to proceed with the project under the BPA EIS and the Supplement Analysis document developed for the project.

PHASE 3: PROJECT IMPLEMENTATION

- With the environmental documentation completed, the third phase of the project was to implement the project described in the planning process. As in all of the stages, a new cooperative team needed to be assembled. This team included the field personnel of BPA, Oregon Department of Agriculture, and the U.S. Forest Service, and the addition of a knowledgeable contractor to perform the work. As a cooperative project, the Zig Zag Ranger District would provide herbicides for the project and the Oregon Department of Agriculture would use their spray truck to spray the access roads. ODA was able to perform work under the Supplement analysis since BPA and the ODA have a state-wide Service Contract and a Memorandum of Understanding, which BPA operated under. ODA's additional responsibility for the project included monitoring for the effectiveness of treatments.
- BPA would hire the contractor and administer the contract for the main workload of the project.
- The U.S. Forest Service would place an announcement in the newspaper of record about the project 30 days before the project begins. They also posted the site before treatment, as prescribed in the supplement analysis.

The contract work on the project started on June 6, 2003, and continued, weather permitting, to the middle of July. Approximately 16.2 hectares to 20.2 hectares (45 acres to 50 acres) of ROW were treated for noxious weeds in the project area using broadcast, handgun methods, herbicide pellets, and backpack application methods of Tordon 22K, Garlon 3A, glyphosate, and dicamba 10G pellets.

In April of 2004, the team reconvened and reviewed the vegetation management activities from 2003 and to plan for vegetation treatments for 2004.

2003 review

It was felt that there was a significant reduction of target species due to the treatments in 2003. Approximately 95% of the infested areas were treated. Areas that were not treated included areas that had significant brush and vegetation hiding target species, areas that extended beyond the reach of the 91 m (300 ft.) handgun hose of the contractor's application equipment, and areas that had surface water in the area.

Water in the area in the early part of the application season was a problem since application to these sites was not allowed. These areas were left with buffers and not treated at all in 2003, or they were treated later in the season when the sites dried up in July.

It was also noted that the road crew had mowed and cleaned the ditches of the main road through the ROW corridor. Soil was removed and dumped in a single location on the site. The contractor will follow-up to treat this soil to make sure this dump site does not become a new problem. The Forest Service contact for the project is working with the road crew in 2004 to resolve any issues.

BPA activities included the removal of selected danger trees located outside of the ROW in the 2003 season.

2004 season

Planning for 2004 included the need to treat the areas missed in 2003, and the review of buffers for herbicide application near water and wetlands. Applications on the site resumed in June of 2003. During June and July 2004, the contractor hired by BPA treated 10.5 hectares (26 acres) of the ROW, and the ODA treated around 4 hectares (10 acres) of ROW.

DISCUSSION AND CONCLUSION

From the initial interagency meeting in June of 2000, to the first treatment of weeds on the right-of-way in the spring of 2003, almost three years passed.

Table 2. Timeline of project

Action	Date
Interagency meeting to initiate project	June 26, 2000
Manual brush treatment of ROW	Fall 2000
BPA EIS checklist and SA process implemented	March 2001
BPA field review and checklist development	July 2001
Award of BA contract w/CH2M Hill	December 11, 2001
USFS Scopes project	Spring 2002
First draft of BA from CH2M Hill	July 2002
Final BA submitted	August 2002
Draft Supplement Analysis submitted to USFS	October 2002
Final Supplement Analysis completed	December 2, 2002
Forest Supervisor concurrence w/project	March 27, 2003
Herbicide applicator contract awarded	April 2003
Herbicide treatments for noxious weeds	June–July 2003
2004 team meeting	April 14, 2004
Herbicide treatments for noxious weeds	June–July 2004

After the initial interagency meeting of June 2000, much of the effort during the next year for analysis and vegetation treatment by BPA was focused on the clearing of trees on the ROW since it had been many years (1990) since the last clearing treatment. During the 1990's, the Zig Zag Ranger District was trying to develop the ROW into a site for the growing Christmas trees and other plant material that could be collected by fee permits by residents of the Portland area. Due to the lack of funding and the turnover of District employees, the concept was finally abandoned in 1999. What was left was a ROW over-grown with woody hardwood vegetation, so the pressure was on the BPA managers to control the vegetation in a timely manner. A BE was developed (Shapiro and Associates, 2000) to control the vegetation manually using US Forest Service procedures. Once this was completed, BPA began to pursue the development of the project as developed by the interagency meeting.

The other factor that extended the process was the BPA EIS, which wasn't published until May of 2000. Another step in the implementation of the EIS was to develop a checklist and the formats for the Supplement Analysis document that tiered the analysis to the BPA EIS. Even though the first Supplement Analysis based on the EIS was developed in July of 2000, the checklist process had not been developed until the late winter of 2001 with the process being fully implemented in March of 2001.

The actual field work and checklist completion started in the summer of 2001. When the checklist was completed, the project moved on to the development of the Biological Evaluation phase with CH2M Hill. During the analysis phase, about 40 percent of the time spent on the project was used to learn and create the process of developing a document that first was acceptable to the BPA but also had to be acceptable to the USFS.

Early on, BPA learned that it was beneficial if we formatted our documents to look similar to U.S. Forest Service analysis documents. This not only involved following the style of the Forest service but also involved the inclusion of additional data and information that is usually contained and referenced in the checklist and placed in the SA. Most BPA SA's are 3–4 pages; the SA for the Big Eddy-Ostrander corridor is 13 pages. When BPA made this accommodation, review periods by the Forest Service shortened. From this process a template for SA's was developed by CH2M Hill to facilitate the process on future projects on U.S. Forest Service lands in the BPA service area.

At times the fire season caused delays due to many of the U.S. Forest Service staff being called out on emergency fires. Documents were sent to the District for review but the reviewers were out for the summer working fires throughout the western States. This problem was solved by contacting Forest Service reviewers in the field and at times on the fire lines via cell phones, and moving documents by fax machines.

Another four months (December 2002 to March 2003) were used in the analysis process for the U.S. Forest Service to concur with our decision and final SA. At least one change was made to facilitate the completion of the analysis process, which allowed BPA to be the exclusive decision maker for the action and requiring only a concurrence letter from the Forest Supervisor. (By not being subject to the U.S. Forest Service's administrative review process, BPA can save up to an additional 90 days of time before implementing projects and perform the project.)

With all that was developed and learned from this first project, a timeline of six months to a year and a half is a realistic period from project conception to implementation for projects such as this when managing vegetation on U.S. Forest Service lands in the Pacific Northwest Region (R6), or even shorter periods of time in other Regions of the U.S. Forest Service.

On June 6, 2003, I received notice that herbicide treatments had started on the Big Eddy-Ostrander Corridor for the treatment of noxious weeds. In the spring of 1991, I first reviewed this stretch of ROW and noticed the need for an Integrated Vegetation Management program to manage vegetation on the corridor. At that time, BPA had been spending at least $10,000 per year for at least 10 years for the hand weeding of diffuse knapweed and other noxious weeds on the project area. The hand cutting of hardwood trees without herbicide treatment had also occurred for many years allowing hardwood trees to dominate the project area.

Initial requests to include the use of herbicides in the vegetation management program on the Forest literally went unanswered for many years. When the decision was made to apply Integrated Vegetation Management methods, a long list of issues needed to be addressed before the use of herbicides on the Forest could even be talked about or considered. By managing this right-of-way without the benefit of Integrated

Vegetation Management, not only the safety and reliability of the transmission lines were in question but it also allowed the expansion of noxious weeds on the right-of-way. This started the process to develop a program to develop an Integrated Vegetation Management program on this section of U.S. Forest Service lands that took 13 years to complete. It took many people from several agencies to work through the process to develop a program to treat weeds and other vegetation on the Mt. Hood Forest. All of these people were instrumental in that first herbicide vegetation treatment on the Big Eddy-Ostrander line.

REFERENCES

Bonneville Power Administration. 2000. Transmission system vegetation management program. Environmental Impact Statement (DOE/EIS-0285). Bonneville Power Administration. Portland, Oregon.

CH2M Hill. 2002. Biological evaluation addendum for the Big Eddy-Ostrander transmission corridor. Bonneville Power Administration. Portland, Oregon.

Dent, J.M. 1956. Trees, shrubs and flowers to know in Washington. The Alger Press Limited, Oshawa, Canada. 211 pp.

Erickson, W.T. and S. Mader. 2002. Environmental checklist: Big Eddy-Ostrander corridor. The Bonneville Power Administration. Walla Walla, Washington.

Goodrich-Mahoney, J.W. 1999. Determination of the effectiveness of herbicide buffer zones in protecting water quality. Electric Power Research Institute, Report No. TR-113160.

Hollen, D.A. 2001. Meeting summary of June 26, 2001. Department of Energy. Bonneville Power Administration. Vancouver, Washington.

Hutchinson, K. and S. Mader. 2002. Supplement analysis for the transmission system vegetation management program. (DOE/EIS-0285/SA-113-1). Bonneville Power Administration. Walla Walla, Washington.

Larson, G.L. 2003. Letter of review-Forest Supervisor's office. Mt Hood National Forest. Sandy, Oregon.

Shapiro and Associates. 2000. Biological evaluation for the Big Eddy-Ostrander transmission corridor (39/3 to 44/5 + 313) vegetation management. Bonneville Power Administration. Portland, Oregon.

USDA Forest Service. 2001. Biological evaluation Lolo pass corridor (Review): USDA Forest Service, Mt. Hood National Forest, Zig Zag Ranger District, Zig Zag, Oregon.

USDA Forest Service. 1988. Final environmental impact statement for managing competitive vegetation. USDA Forest Service Region 6. Portland, Oregon.

BIOGRAPHICAL SKETCH

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Purple Loosestrife Biological Control Program

H. Wayne Harper

Purple loosestrife (*Lythrum salicaria L.*) is a beautiful but aggressive invasive plant species that has adversely affected wetlands throughout many areas of southern Canada and the northern United States. During and following the construction of the Portland Natural Gas Transmission System (PNGTS) pipelines within northern New England, the project was charged with the task of controlling of this pervasive invader. After surveying the post-construction extent of infestation along its rights-of-way, PNGTS implemented a biological control program in conjunction with the New Hampshire Department of Environmental Services. Selected varieties of the plant's natural insect predators from Europe were introduced into problematic areas. The goal of this program was not to completely eradicate purple loosestrife, but bring the plant populations into acceptable levels of infestation. This report documents this work effort.

Keywords: Purple loosestrife, biological control, invasive species, nuisance species

INVASIVE SPECIES

Exotic plant species are defined as those that are either intentionally or unintentionally introduced into a geographic area to which they are not native. While not all exotic plant species are classified as nuisance species, when their populations grow in a given area to the point where they cannot be naturally controlled and begin to out-compete indigenous plant species, they may then be considered nuisance/invasive species.

PURPLE LOOSESTRIFE

Purple loosestrife (*Lythrum salicaria* L.) is a beautiful but aggressive perennial invader that arrived in eastern North America in the early 1800's. It is believed that the plants were brought to North America by settlers for their flower gardens and seeds were present in the ballast holds of European ships that used soil to weigh down the vessels for stability on the ocean (Illinois – Indiana Sea Grant, 2004). A general description of this plant species is provided below (see also Fig. 1):

- Leaves: Green, smooth, lance-shaped, opposite/whorled, often downy
- Stems: 4-sided and woody (4–7 feet tall)
- Flowers: Purple-pink (5–7 petals), arranged in a dense spike
- Each mature plant produces 30 or more spikes
- Each spike can produce over 2.5 million seeds per year
- Season: Flowers mid July to September
- Habitat: Wetland shorelines, roadside, drainage, and irrigation ditches, to moist agricultural fields

Since its introduction, purple loosestrife has spread westward and can be found across much of Canada and the United States (Purdue University Entomology Department, 2004) (see Fig. 2). This pervasive invader is impressive in its ability to rapidly degrade wetlands and diminish their value for wildlife habitat. Wetlands are the most biologically diverse, productive component of our ecosystem. Hundreds of species of plants, birds, mammals, reptiles, insects, fish and amphibians rely on healthy wetland habitat for their survival. However, when purple loosestrife becomes established, the habitat where wildlife feed, seek shelter, reproduce and rear young, quickly becomes impaired. An estimated 190,000 hectares of wetlands, marshes, pastures and riparian meadows are affected in North America each year, with an economic impact of millions of dollars. Purple loosestrife also invades drier sites. Concern is increasing as the plant becomes more common on agricultural land, encroaching on farmers' crops and pasture land (Illinois – Indiana Sea Grant, 2004).

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Fig. 1. Purple loosestrife (*Lythrum salicaria* L.).

PNGTS INVASIVE SPECIES MONITORING PROGRAM – 2001

Following construction and during restoration of the Portland Natural Gas Transmission System (PNGTS) Pipeline and Joint Facilities pipelines within northern New England, invasive species surveys of the approximately 200-miles of rights-of-way were conducted in the summer of 2001. The intent of this qualitative and generalized quantitative review of project areas was to determine the extent and location of two invasive plant species populations, purple loosestrife and common reed (*Phragmites australis* (Cav.)). Specifically, all project wetlands and surrounding areas were monitored during the later portion of the growing season. This time period was selected because both invasive species are easily identifiable, with the distinctive flower of purple loosestrife in full bloom and the fluffy gray/tan seed heads of common reed fully developed. This *Invasive Species Monitoring Program* was designed with specific monitoring protocols to achieve two main goals: first, to distinguish between those areas where invasive species pre-existed the construction of the Project, and secondly to identify newly infested areas.

The results of the *Invasive Species Monitoring Program*, which documented population patterns for purple loosestrife and common reed along the PNGTS and Joint Facilities pipelines at that time can be summarized as follows:

- *PNGTS North-Section Pipeline* - Though common reed was not identified on-ROW, purple loosestrife was present throughout the project areas in sporadic locations and in varying degrees. In the majority of

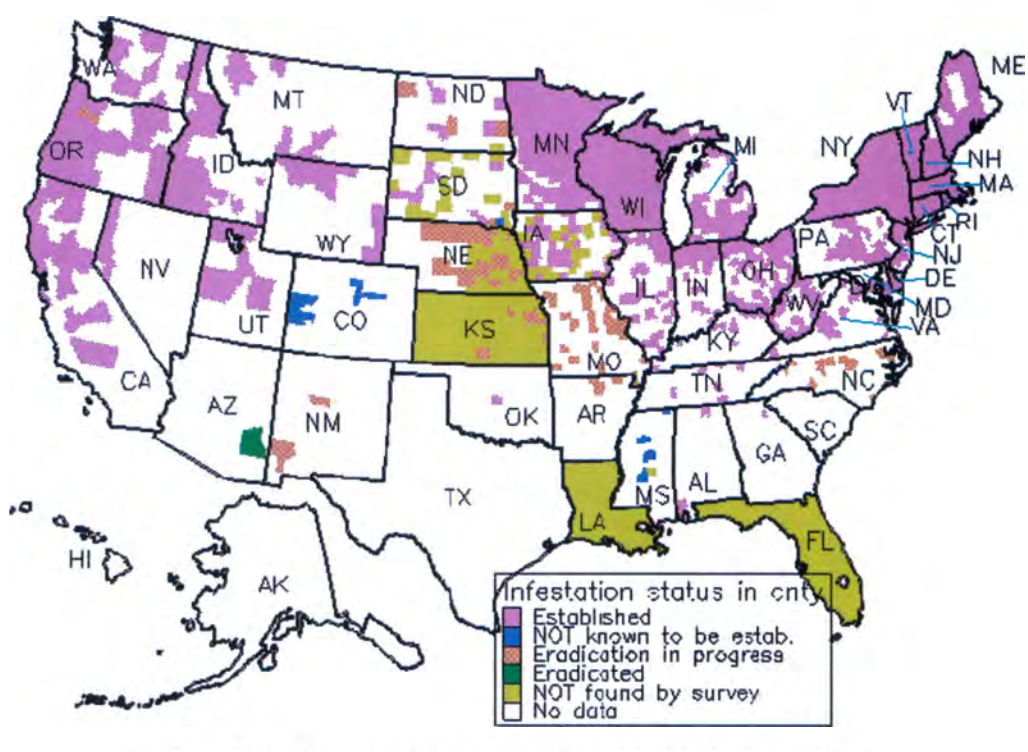

Fig. 2. 2004 infestation status of purple loosestrife within the United States.

areas, purple loosestrife existed on-ROW but was not located off-ROW. It is assumed these newly infested areas were due to construction related activities.

- *Joint Facilities Pipeline* - While common reed was identified as a new infestation in only three wetlands, purple loosestrife was well established and widespread throughout southern New Hampshire and portions of southern Maine. The extent of purple loosestrife infestation was characterized as a regional problem, thus any proposed approach to its reduction and/or eradication should be tailored to this constraint.

PURPLE LOOSESTRIFE MITIGATION

In areas of severe purple loosestrife infestation, manual and chemical control efforts typically are ineffective and may in fact contribute to the problem (Illinois – Indiana Sea Grant, 2004). This is primarily due to the incidental spreading of seeds during manual removal and the re-establishment of purple loosestrife plants from remnant root systems following manual or chemical control efforts. However, the use of specifically selected insects that feed on purple loosestrife has proven successful in numerous "high density infestation area" projects throughout the United States. These biological control programs have demonstrated that the re-introduction of purple loosestrife to its natural "European" predators will, with time, not completely eradicate the plant but reduce the overall numbers and lessen their ability to displace native vegetation. Following the release of these agents, their populations will increase, spread regionally, and ultimately reach equilibrium with the food source. Special care and significant testing must occur to ensure that proposed biological control agents will not have unintended adverse affects on indigenous plant species within the target region. As such, biological agent release projects are regulated and typically monitored by state environmental agencies.

PNGTS BIOLOGICAL CONTROL OF PURPLE LOOSESTRIFE

In response to the purple loosestrife infestations along the project rights-of-way, PNGTS proposed utilizing a combination of biological control agents and manual plant removal. Generally, biological control agents (beetles) would be applied in the most problematic areas in New Hampshire, while manual removal would occur along the rights-of-way within Maine.

The biological control approach was presented to the New Hampshire Department of Environmental Services (NH-DES) and ultimately approved within the constraints of an official release and monitoring program. Specifically, the biological control agents selected by the NH-DES for purple loosestrife mitigation include two beetle species: *Galerucella calmariensis* (L.) and *G. pusilla* (Duft.) (Coleoptera: Chrysomelidae) (see Fig. 3). Details of the *Purple Loosestrife Biological Con-*

Fig. 3. Purple loosestrife with biological control agent (*Galerucella spp.*).

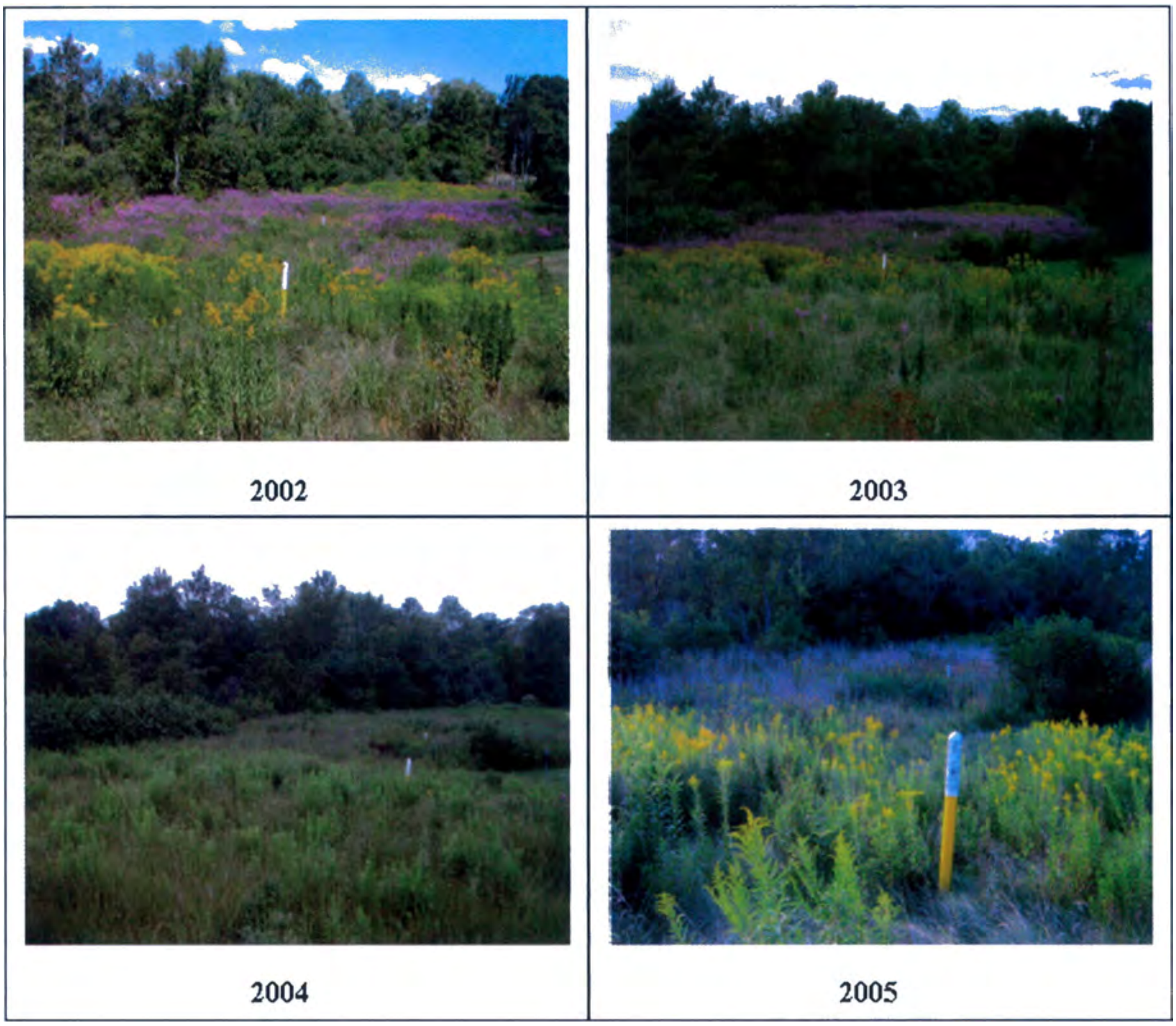

Fig. 4. Site #11 – 2002, 2003, 2004, and 2005.

trol Program (Program) components for the PNGTS and Joint Facilities pipeline rights-of-way are outlined below:

- 14 sites with corresponding release amounts selected by the NH-DES;
- 20,000 beetles total released for all sites per year for a period of 4-years;
- PNGTS to conduct annual monitoring and reporting for 4-years; and,
- at the end of the 4-year period, PNGTS' obligation for purple loosestrife mitigation for New Hampshire shall be completed.

2002 TO 2005 DATA ANALYSIS

From site-specific monitoring data and comparative observations, general conclusions on the current health and vitality of purple loosestrife populations along the PNGTS North-section and Joint Facilities pipeline rights-of-way were determined. These summations are presented in outline form below:

- Colonies of purple loosestrife can be divided into two distinct populations: 1) plants that re-emerge from previously established root stock developing quickly and with significant vigor, and 2) new plants emerging from the previous year's dispersed seeds. This second group develops in a time-delayed position as compared to the root stock emergent group.
- Total purple loosestrife populations in 2005 within the pipeline route region appear to be generally consistent, if not increasing, as compared to previous years. This, however, is not represented well in the Program's monitoring data due to site-specific changing conditions observed within the actual monitoring site wetlands. Specifically, significant hydraulic changes with 25% of the Program's site wetlands have dramatically affected plant distributions within these areas.
- Upon release, the beetles fly and distribute themselves on and off the pipeline right-of-way. While feeding damage has consistently been observed within the monitoring grids, the overall damage to

Fig. 5. Site #11 significant leaf damage.

the purple loosestrife population is not currently significant in almost all areas. This is due to the still relatively small number of feeding beetles as compared to the overabundant purple loosestrife food supply. It is still anticipated that the beetle population will continue to increase, and with time, ultimately have a reducing effect on the extent of regional purple loosestrife.

- Monitoring at site #11 has confirmed success, with the Program's biological control goals, by demonstrating a significant and detrimental effect on the existing purple loosestrife population within this wetland complex. Site #11 is bordered on the western and eastern sides by residential development and on the northeast and southeast sides by upland/roads. The purple loosestrife within this wetland complex is comparatively isolated. As such, the previously released beetles did not disperse to the surrounding area in great numbers. The result of this was concentrated reproduction and feeding in and around this wetland complex. During the year 2005 monitoring, significant leaf damage, greatly diminished vigor, and no flowering stems were observed for all purple loosestrife plants. The situation exemplifies what is hopeful for Project areas once beetle populations reach adequate levels. Figure 4 depicts site #11 through the four years of Program monitoring while Figure 5 documents a sample of the significant leaf damage observed in 2005.

REFERENCES

Anderson, M.G. 1995. Interactions Between *Lythrum salicaria* and Native Organisms: A Critical Review. Environmental Management. Vol. 19, No. 2.

Brown, L. 1979. Grasses: An Identification Guide. Houghton Mifflin Company.

Illinois – Indiana Sea Grant. 2004. Purple Loosestrife – Exotic Aquatics on the Move. [http://www.iisgcp.org/EXOTICSP/purple_loostrife.htm].
Ontario Federation of Anglers & Hunters. 2001. Purple Loosestrife: What You Should Know, What You Can Do (brochure).
Purdue University Entomology Department. 2004. The Center for Environmental and Regulatory Information System (CERIS). Reported Status of Lythrum (Loosestrife); Purple, Lythrum Salicaria. [http//ceris.purdue.edu/napis/pests/pls/mgif/plsall.gif].
Stuckey, R.L. 1980. Distributional History of *Lythrum salicaria* in North America. Bartonia, 47: 3–20.
Tiner, R.W., Jr. 1987. Coastal Wetland Plants of Northeastern United States. The University of Massachusetts Press.
Voegtlin, D.J. 1994. A Biological Control for Purple Loosestrife? Illinois Natural History Survey Reports. May/June.
Welling, C.H. and R.L. Becker. 1990. Seed bank dynamics of *Lythrum Salicaria* L.: implications for control of this species in North America. Aquatic Botanist, 38: 303–309.

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Vegetation Management of Woody Deciduous Species with the Biological Herbicide *Chondrostereum purpureum*

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In recent years, biological control products have been considered to be a useful addition to an integrated pesticide management plan, especially when chemical pesticide use is increasingly constrained. The management of woody deciduous species is a challenge in industrial rights-of-way. These tree species grow rapidly and have the ability to re-sprout from cut stumps when chemical herbicides are not applied. In riparian zones and in management areas where chemical herbicide use is no longer permitted, there are limited choices for the control of these species. As a solution to these management constraints, we have been developing the fungus *Chondrostereum purpureum* as a viable alternative to chemical herbicide application for the control of deciduous species. This biological herbicide has shown efficacy against red alder, Sitka alder and aspen in field trials that is comparable to chemical methods of deciduous brush control. Concurrent studies that evaluated the environmental fate and the non-target effects of this fungus have determined that it is a safe alternative to chemical methods of weed control. This biocontrol agent could be an important component of an integrated vegetation management strategy, especially in rights-of-way that traverse wetlands and environmentally sensitive habitats. A formulation of this bioherbicide has been registered for use in both Canada and the United States. Product efficacy against a wider range of target tree species will be evaluated in future field trials.

Keywords: Bioherbicide, biocontrol, riparian zones, re-sprouting, fungus, ROW

INTRODUCTION

The following discussion will consider our research work in relation to the broader picture of biological control, with an emphasis on vegetation management and the challenges it presents for biological herbicides (bioherbicides). Our research group has been involved with the development of the phytopathogenic fungus *Chondrostereum purpureum* as a bioherbicide for the control of woody deciduous species in industrial rights-of-way (ROW) and forestry management. A formulation of this bioherbicide was submitted for joint review and registration to the Pest Management Regulatory Agency (Canada) and the Environmental Protection Agency (United States). Regulatory approval of this product was granted by both agencies in August of 2006.

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THE FUTURE OF BIOLOGICAL CONTROL AGENTS

The interest in and the active use of biocontrol agents has been increasing over the past decade. This trend is related to several factors, including improved transfer of technologies from the discovery stage to the development of a viable product, the support of these research efforts by user groups, and the demand from the general public for alternatives to chemical methods of pest and weed control.

Some sectors of horticulture and agriculture have seen a substantial increase in biopesticide use, specifically for high-value crops grown in the greenhouse sector, where the controlled environment lends itself well to the use of a variety of biocontrol methods.

Biocontrol products and strategies have been successfully integrated into pest management plans for greenhouse operations. They have been shown to be effective in maintaining crop quality and provide cost-competitive pest and disease control, when compared to traditional approaches (Applied Bio-nomics, Ltd, 1993; Jarvis, 1995).

The steady growth of organic agriculture in response to consumer demand for organic products has also supported the increased use of biocontrol agents as part of the integrated pest management approach favoured in this sector (Willer and Yussefi, 2004).

In the more traditional sectors of agriculture and forest pest management, bacterial (*Bacillus thuringiensis*) and virus-based products have been used to target a number of insect pest species, with varying degrees of success. These pest control products continue to be refined in order to target specific pest species and minimize non-target effects (Glare and O'Callaghan, 2000; Joung and Côté, 2000).

Numerous municipalities across Canada have adopted legislation that limits or bans cosmetic use of chemical pesticides on public and private property in urban centers. To date, at least 66 municipalities, containing about 35% of Canada's population, have passed new by-laws that regulate pesticides (Wobschall, 2004). With the development of more strict guidelines for chemical pesticide use in urban settings, pest and vegetation managers have voiced their concerns that few options are available to them. Effective biocontrol products are needed to address pest control needs in this sector and presents a novel opportunity to researchers in this field. At the same time, there is a continued interest from the domestic market for biocontrol products designed for home and garden use, where the range of products available currently are limited.

ADVANTAGES OF USE OF BIOLOGICAL CONTROL AGENTS

Pressure from the general public to reduce or eliminate chemical methods of pest control is an issue in both urban and rural settings. Questions are often raised regarding the impact of pesticide use on public health, water quality in streams and groundwater, and on the natural environment. The validity of these concerns does vary, but must be addressed to the satisfaction of the parties concerned. In addition to the pesticide regulatory review process, regulatory agencies have responded appropriately by restricting chemical pesticide use to protect water quality, aquatic habitats and to minimize the impact upon natural ecosystems and non-target species. In pesticide-free zones, or areas of limited pesticide use, biocontrol agents can be both a suitable alternative and an effective management tool. Effective biocontrol products will allow managers to attain an acceptable level of pest/weed control, while responding to criteria of pesticide safety.

In addition to public health and environmental impact, worker safety is an important issue. Pesticide applicators probably receive the highest level of exposure of any group and there is the potential for them to develop health problems associated with long-term exposure to chemical herbicides. This concern has been voiced by many vegetation management workers who work with chemical products on a regular basis. The adoption of effective biocontrol products will improve worker safety over the long-term by reducing their exposure to chemical products (Riley and Siemsen-Newman, 2001).

Biocontrol agents may be added as another tool in an integrated pest/vegetation management plan. They will contribute to reduced chemical pesticide use and provide more flexibility for effective weed/pest management. Resistance to chemical pesticides can develop over time with repeated use against target species (Holt, 1992). Inclusion of biocontrol agents in an IPM/IVM plan can reduce the strong selection for resistant individuals in a pest population. Biocontrol agents usually have a different mode of action against the target species, when compared to chemical methods of control. They may also suppress the target species by use of more than one mode of action. Consequently, resistance to biocontrol agents will be much less likely to develop among target species (Boyetchko, 1999; Boyetchko et al., 1998; Zidack and Quimby, 1998).

Persistence in the environment of the active ingredient of a biocontrol agent generally is not a concern. Biocontrol products are often applied using an inundative approach that effectively creates a localized disease epidemic in the target population (Charudattan, 2000; 2001). Once the target species is reduced to a low level, the population of the biocontrol agent dissipates to a level similar to that of the background population of that species (Charudattan, 1991; Templeton et al., 1979). The persistence of chemical pesticides in the environment is highly variable and will be influenced by their chemical properties and by the environmental conditions (Rao and Hornsby, 2001).

FEATURES OF BIOLOGICAL CONTROL AGENTS

Biocontrol agents do present some challenges, due to the fact that the active ingredient is a living organism. The range of target species that can be effectively suppressed may not be as broad as a chemical method of control. A single genotype of a biocontrol agent typically will be an effective control agent on a limited number of target species. The geographical origin of the biocontrol species may be a factor in the determination of susceptible target species. It may be necessary to identify isolates collected from different geographical regions, which are adapted for target hosts native to those same areas. Numerous genotypes of a biocontrol agent may be needed to be screened to identify those effective against more recalcitrant target pest species.

More effective biocontrol agents might exist with a wider effective range, but negative impacts on non-target species are an important consideration in the selection of biocontrol agents. The criteria used to select and screen a biocontrol agent have prudently adopted a cautious approach, in order to minimize non-target impacts when used on a large scale. The result of this selection strategy is perhaps a less virulent control agent, but also a safer control agent, in terms of its non-target effects.

Individual registered biocontrol agents are often considered as niche products, with a more limited range of target species. Each registered product typically is a single genotype of the control agent. This has contributed to slow commercialization of many such agents and the reluctance of major pesticide manufacturers to fund/support the development of more specialized agents. This leaves room for individual entrepreneurs to develop niche markets. The chemicals industry is beginning to recognize that the benefit of increased host specificity will be reduced impacts upon non-target species, a feature that is becoming increasingly important in pest control.

The optimal weather conditions required and the recommended season of use to obtain the greatest efficacy of a biocontrol agent may impose some limitations on the application of biocontrol agents. The effective use of biocontrol agents may therefore require more careful planning, if they are to be used as a component of IPM/IVM plans. When using a living control agent, the conditions on the site of application must be carefully evaluated, so as to stay within the acceptable limits for survival of the active ingredient and permit successful colonization of the target host. Pesticide managers must therefore have a good understanding of the effective range of use and the preferred conditions for good colonization or infection by the biocontrol product in question. To this end, use of a biocontrol agent will require some additional training of applicators to insure optimal care of the agent and the proper application to the target pest species. Should biocontrol products be kept on hand for possible use, it should be noted that they have a limited shelf life and their storage must observe a specific temperature range to maintain product viability, as described on the product label.

FINANCIAL CONSIDERATIONS WITH BIOLOGICAL CONTROL AGENTS

In order for biocontrol agents to be widely accepted, they must become cost competitive with existing methods of control. In some instances, chemical methods are no longer permitted and a biocontrol agent might be the only alternative. In many pest management situations, however, there is a choice between chemical and biological methods of pest control; the comparative cost of the control methods can often be the deciding factor in their selection.

The initial training of staff and the adaptation of application equipment can contribute to a greater initial cost for biological agents, but the benefits will become apparent in the long term, should the method prove to be of comparable efficacy to existing methods. Should the biological control agent be added to the pest management plan, it may result in more cost-effective control of pest species over the long term. The area covered by a pest management plan will likely include pesticide-free zones, where the use of biocontrol agents may be permissible. In situations where pesticide resistance has become a problem, the adoption of biocontrol agents will provide an added benefit. The existence of single or multiple herbicide resistance among major agricultural weed species inflates the cost of weed control and reduces crop yield (Beckie et al., 1999; Boyetchko, 1999; Boyetchko et al., 1998). An effective bioherbicide used in this vegetation management situation will release the crop from competition and reduce the selection for herbicide-resistant plant genotypes, since it will inhibit weed growth by a different mode of action. As part of an IVM plan, a bioherbicide can contribute to cost savings.

The phytopathogenic basidiomycete fungus *Chondrostereum purpureum* has excellent potential as a biological control agent of North American deciduous tree species (Becker et al., 1999a, b; Pitt et al., 1999; Spiers et al., 1998; Jobidon, 1998; Dumas et al., 1997; Wall, 1990; 1991; 1994). This fungus has been the subject of research in our laboratory for a number of years. In areas where chemical pesticide use is no longer permitted, a formulation of *C. purpureum* can provide good suppression of resprouting by decidous tree species. Mechanical cutting alone will result in a higher stem density and increased cutting costs over time. Use of *C. purpureum* can reduce this stem density and in turn reduce the cost of mechanical methods of control, which usually incur high labour costs. The use of *C. purpureum* can therefore be cost competitive with mechanical methods of control, depending on species treated and site conditions.

A formulation of the product has received temporary registration in Canada. This temporary registration of the paste formulation of *C. purpureum* does not require a buffer zone when it is applied in the proximity of non-target tree species, since healthy, non-wounded trees are at negligible risk. As well, no restriction has been identified for its use in riparian zones, in the proximity of waterways. This designation will provide an advantage to this product, since pesticide use typically is not permitted in riparian areas. A regulatory decision concerning the Environmental Protection Agency (EPA) registration of the paste formulation for use in the United States is pending.

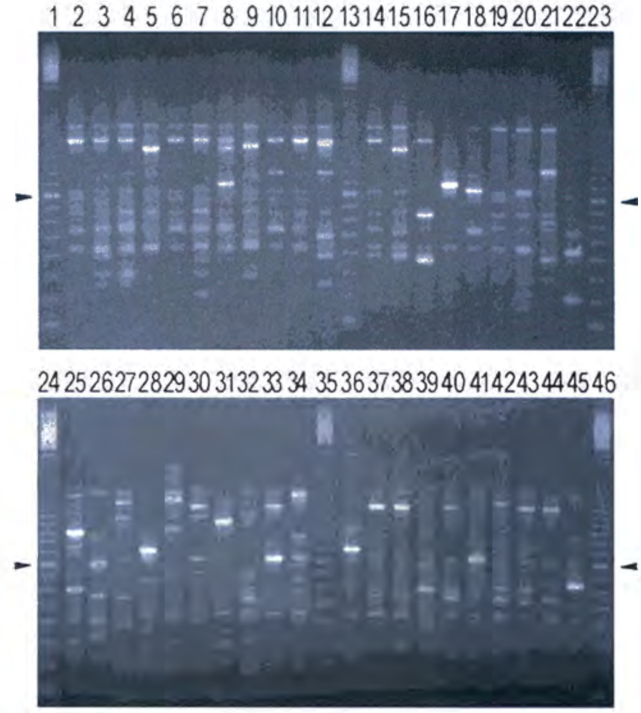
DETERMINING EFFICACY AND ENVIRONMENTAL FATE

Since a biocontrol agent is a living organism, it is very important to be able to determine with certainty the impact of large-scale use. This includes being able to demonstrate and confirm product efficacy against the target species, as well as being capable of monitoring the environmental fate of the biocontrol genotype. DNA fingerprinting methods are the most reliable techniques to attain these objectives, since it is possible to identify a specific genotype of a biocontrol agent.

Our own research on *C. purpureum* illustrates this approach. This fungus is a weak pathogen of a wide range of woody, deciduous plant species and is distributed throughout temperate forests of North America. It was identified as a biological control agent of deciduous tree species, for use in industrial rights-of-way and forestry. As part of our research program, genetic markers were developed to monitor the environmental fate of field-inoculated strains, evaluate strain efficacy in field trials and to study the population structure of this species. These genetic markers are based on sequence characterized amplified region (SCAR) PCR primers that amplify a collection of variable-length fragments from the target genomic DNA of a *C. purpureum* strain. This method provides a unique, reproducible polymorphic banding pattern for each fungal genotype. These sequences identified in *C. purpureum* represent incomplete retrotransposon elements that are translationally inactive. These sequences occur in multiple DNA fragments of variable length for a given *C. purpureum* isolate and are neutral in character, features well suited to their use as strain-specific genetic markers (Becker et al., 2004).

Monitoring the environmental fate of a selected biocontrol genotype is important since it will give a more clear indication of the possible impact of its large-scale use. The application of a biocontrol agent creates a small disease epidemic, which ideally should be limited to the target site and target species long enough to control the pest/weed. The introduction of a single genotype on a large scale has the potential to modify the population structure of the wild biocontrol species, which is a major consideration in the selection of a biocontrol agent. A balance needs to be struck between an effective control agent and acceptable risk to non-target species. For the species *C. purpureum*, the presence of a fresh wound and not the basidiospore load, is considered to be the primary factor determining a non-target host tree's risk of infection. The spore load generated by the basidiocarps of an inoculated strain of this fungus is expected to be of the same order of magnitude or lower than naturally occurring levels (DeJong et al., 1996).

Population structure and gene flow in two geographically separated populations of *C. purpureum* were evaluated with the SCAR genetic markers. These



Isolates shown include F0301 (lane 2), F0302 (lane 3), F0303 (lane 4), F0304 (lane 5), F0305 (lane 6), F0306 (lane 7), F0308 (lane 8), F0309 (lane 9), F0310 (lane 10), F0311 (lane 11), F0312 (lane 12), F0315 (lane 14), F0345 (lane 15), F0346 (lane 16), F0347 (lane 17), F0348 (lane 18), F0349 (lane 19), F0351 (lane 20), F0353 (lane 21), F0354 (lane 22), F0387 (lane 25), F0393 (lane 26), F0395 (lane 27), F0396 (lane 28), F0397 (lane 29), F0398 (lane 30), F0399 (lane 31), F0401 (lane 32), F0402 (lane 33), F0404 (lane 34), F0410 (lane 36), F0411 (lane 37), F0414 (lane 38), F0415 (lane 39), F0416 (lane 40), F0417 (lane 41), F0418 (lane 42), F0419 (lane 43), F0420 (lane 44), and F0421 (lane 45). Size markers (100 bp) are shown in lanes 1, 13, 23, 24, 35, and 46, with the 800 bp band indicated.

Fig. 1. Amplification of *C. purpureum* isolates from Mission and Kemano, B.C. using APD13F+R primers.

two sites (Mission and Kemano) are located in the same ecological zone, about 1400 km apart in British Columbia (B.C.), Canada. Isolates of *C. purpureum* were collected from *Alnus*, *Populus* and *Salix spp.* host trees at the Mission site, under power line rights-of-way, while all collections of *C. purpureum* at the Kemano site were from *Alnus rubra* hosts. A unique banding pattern was observed for each genetic individual tested (Fig. 1).

Phenetic analysis was completed to make inferences about the population structure of *C. purpureum* (Molecular Analyst, 1997). The dendogram produced by the Un-weighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm showed no population substructuring, with no apparent clustering for host tree, or geographical origin of isolates (Fig. 2). These observations suggest that, on the scale of this study, there are no barriers to gene flow among populations of *C. purpureum* within B.C. Population substructuring might have indicated that isolates from the two regions did not freely interbreed. There was also no evidence of se-

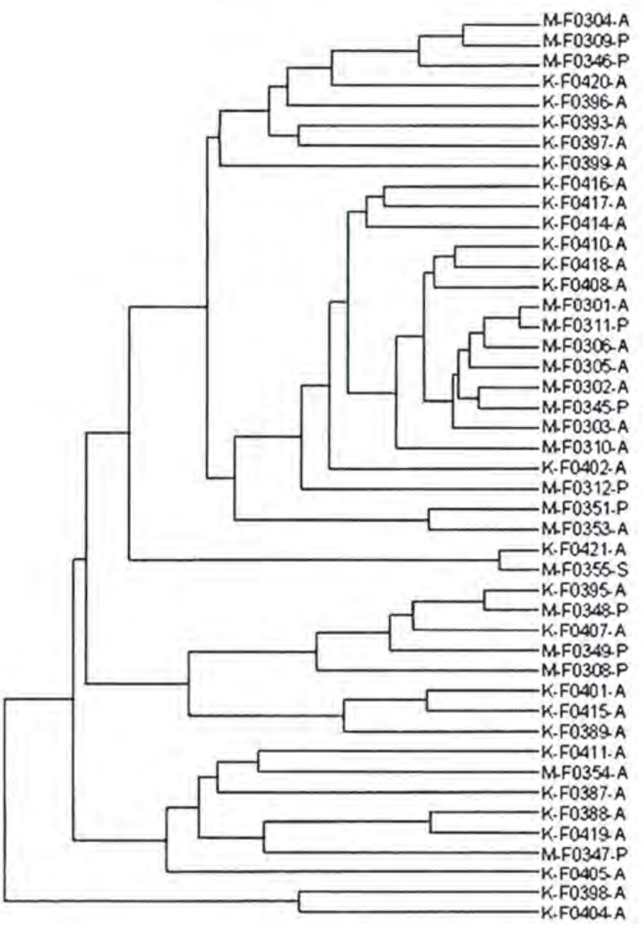


Fig. 2. Dendogram representing C. purpureum from Kemano and Mission, B.C. Similarity coefficients (Dice's) were derived from comparisons of APD13 amplification patterns among all isolates and clustered using the UPGMA algorithm. Accession numbers for each C. purpureum isolate are preceded by an M (Mission) or K (Kemano) to denote their geographical source and followed by an A (Alnus rubra), P (Populus), or S (Salix) to signify the host tree from which they were collected.

lective pressures strong enough to result in clusters of genetically similar isolates, based on host or geographical specificity.

The lack of geographical or host specificity by *C. purpureum* in B.C. provides evidence that there would be minimal risk to using a single genetic individual for biocontrol applications in B.C. Our lead isolate would likely cross with other genotypes present on the site of application, thus contributing to outcrossing and preventing clonal development of single fungal genotypes. Our conclusions are in agreement with the findings of previous studies of risk analyses conducted over larger geographical areas. These studies evaluated the genetic variability of *C. purpureum* in North America, Europe and New Zealand using nuclear and mitochondrial DNA markers (Ramsfield et al., 1996; 1999), within Canada using protein patterns (Ekramoddoullah et al., 1993) and within eastern Canada using RAPD loci (Gosselin, 1999a).

Characteristics of the life history of *C. purpureum* appear to promote gene flow among populations rather than produce isolated pockets of similar genotypes. This is supported by the results of our population analyses. Conidial spore production is absent in this species, which normally would promote the clonal propagation of genotypes. The primary form of dispersal for this species is therefore the meiotically-produced basidiospore. This feature, combined with the tetrapolar, heterothallic mating system of *C. purpureum* strongly promotes gene flow among populations (Wall et al., 1996). The multi-allelic nature of the A and B mating type loci will likely result in a high level of compatibility for mated homokaryons from geographically disparate populations and thus further promote outcrossing (Wall, Macey and Sela, 1996; Boidin, 1986; Rayner and Boddy, 1986; Stankis et al., 1992). This fungus is a weak pathogen that will infect fresh wounds of injured trees and is known to have a broad host range that includes a number of deciduous tree species (Wall, 1996).

EFFECTIVE METHODS OF PRODUCTION AND FORMULATION OF A BIOPESTICIDE

The development of an effective production system and an appropriate product formulation are often the determining factors in the success of a biocontrol agent.

An effective production system should have the ability to be scaled-up to meet demand as required. It should also be capable of producing an active ingredient of consistent quality and activity, while maintaining recognized standards of quality control. An acceptable formulation should be easy to apply with existing application equipment, maintain product viability to permit the infection of the target species, and demonstrate good efficacy under typical conditions of use. It should also be easy and inexpensive to transport to the site of use. Both of these aspects have been discussed in more detail in de la Bastide et al. (2002).

The current formulation under regulatory review in Canada and the United States is a paste formulation that has demonstrated good efficacy for alder (red alder, Sitka alder) and aspen (trembling aspen) species (de la Bastide et al., 2002). A second formulation under development is a spray suspension that has shown good efficacy in a study on red alder (*Alnus rubra*) on Vancouver Island (Table 1). Further trials are needed to confirm the efficacy of this formulation on red alder and on other tree species. It will also be important to evaluate the spray formulation under different conditions of use in the field, to determine the optimal conditions for product efficacy.

THE REGULATORY PROCESS

The regulatory requirements for North American pesticide product review provide a balanced assessment

Table 1. Summary of spray formulation trial on Vancouver Island. Mortality of treated stumps is shown two years following treatment with spray formulation

Location, year and tree species	Treatment	Second year % mortality
Nanaimo Lakes, B.C.	Area 1	86.8
1999	Area 2	91.9
Red Alder	Area 3	81.1
	Control area	67.4

of a given biopesticide product. The regulatory process, however, would be assisted by some improvements, as follows:

- Granting of additional resources for regulatory agencies, since current work load is likely a limiting factor in the progress of product registrations.
- Increased input from user groups for specific categories of biocontrol products, indicating where the needs are most urgent. This will also help to identify key areas of research and product development.
- Increased attention to the needs of the general public and their desire for alternatives to chemical methods of control should be reflected in regulatory policy. The advent of new pesticide by-laws in many jurisdictions confirm this growing demand.
- The registration time line is too long and needs to be shortened. On top of the long product development phase, the long registration time line discourages private funding of such development projects, since the time required to realize a return on investment is lengthy. This is a major obstacle for small start-up companies with limited financial resources.
- Many biocontrol products are considered to be niche products with smaller markets than major chemical pesticides. Consequently, larger biotech companies are less interested in developing these products. Large companies will certainly have the financial resources to develop and register these products, but the task often falls to a smaller company with limited resources. How can this disparity be resolved to insure that new products continue to be developed and registered?

PUBLIC AND PRIVATE SUPPORT OF BIOLOGICAL CONTROL – THE BIOCONTROL NETWORK

In an effort to improve the communication and collaboration between user groups, researchers and industry, as well as product development, a Canadian research network has been established on the theme of biological control. The Biocontrol Network supports research collaborations among private and public sector partners working on common research themes. The network targets 2 main areas, namely the greenhouse and tree nursery industries and focuses on developing biological methods to pest management. The Network also fosters cooperation with different user groups of biocontrol agents, with the goal of creating new knowledge and expertise and facilitating its transfer to industry. Such focused efforts should result in the development and commercialization of more biocontrol agents and train more qualified scientists in this field. The Biocontrol Network is funded by Canada's Natural Sciences and Engineering Research Council (NSERC). For more details on the Network, consult their website (http://biocontr.prestosite.net).

REFERENCES

Applied Bio-nomics, Ltd. (ed). 1993. Biological Technical Manual. Applied Bio-nomics, Ltd., Sidney, B.C. 490 p.

Becker, E.M., L.A. Ball, and W.E. Hintz. 1999a. PCR-based genetic markers for detection and infection frequency analysis of the biocontrol fungus *Chondrostereum purpureum* on Sikta Alder and Trembling Aspen. Biological Control, 15: 71–80.

Becker, E.M., L.A. Ball, M.T. Dumas, D.G. Pitt, R.E. Wall, and W.E. Hintz. 1999b. *Chondrostereum purpureum* as a biological control agent in forest vegetation management. III. Infection survey of a national field trial. Can. J. For. Res., 29: 859–865.

Becker, E.M., P.Y. de la Bastide, and W.E. Hintz. 2004. A retrotransposon-like element and its occurrence in British Columbia populations of *Chondrostereum purpureum*. Fungal Genetics and Biology, 41: 921–929.

Beckie, H.G., A.G. Thomas, and A. Legere. 1999. Nature, occurrence and cost of herbicide-resistant green foxtail (*Setaria viridis*) across Saskatchewan ecoregions. Weed Technol., 13: 626–631.

Boidin, J. 1986. Intercompatibility and the species concept in the saprobic basidiomycotina. Mycotaxon, 26: 319–336.

Boyetchko, S., E. Pedersen, Z. Punja, and M. Reddy. 1998. Formulation of biopesticides, pp. 487–508, *In* F.R. Hall and J.J. Menn (Eds.), Biopesticides: Use and Delivery. Methods in Biotechnology Vol. 5, Humana Press, Inc., New Jersey.

Boyetchko, S.M. 1999. Innovative applications of microbial agents for biological weed control. pp. 73–97, In: Mukerji, K.G.; Chamola, B.P.; Upadhyay, Rajeev K. (Eds.), Biotechnological Approaches in Biocontrol of Plant Pathogens. Kluwer Academic/Plenum Publishers, New York. 268 p.

Charudattan, R. 1991. The mycoherbicide approach with plant pathogens. In: Microbial Control of Weeds. Edited by D.O. TeBeest, Chapman and Hall, New York. pp. 24–57.

Charudattan, R. 2000. Current Status of Biological Control of Weeds pp. 269–288, In: G.G. Kennedy and T.B. Sutton (Eds.), Emerging Technologies for Integrated Pest Management: Concepts, Research, and Implementation. Proceeding of a Conference, March 8–10, 1999, Raleigh, NC. APS Press, St. Paul, MN.

Charudattan, R. 2001. Biological control of weeds by means of plant pathogens: Significance for integrated weed management in modern agro-ecology. BioControl, 46: 229–260.

De Jong, M.D., E. Sela, S.F. Shamoun, and R.E. Wall. 1996. Natural occurance of *Chondrostereum purpureum* in relation to its use as a biological control agent in Canadian forests. Biological Control, 6: 347–352.

De la Bastide, P.Y., H. Zhu, G. Shrimpton, S.F. Shamoun, and W. Hintz. 2002. *Chondrostereum purpureum*: an alternative to chemical herbicide brush control. pp. 665–672. In: Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (Eds.). Elesvier Science Ltd.

Dumas, M.T., J.E. Wood, E.G. Mitchell, and N.W. Boyonoski. 1997. Control of stump sprouting of *Populus tremuloides* and *P. grandidentata* by inoculation with *Chondrostereum purpureum*. Biol. Contr., 10: 37–41.

Ekramoddoullah, A.K.M., S.F. Shamoun, and R.E. Wall. 1993. Comparison of Canadian isolates of *Chondrostereum purpureum* with respect to temperature response, virulence, and protein profiles. Can. J. Plant Pathol., 15: 7–13.

Glare, T.R. and M. O'Callaghan. 2000. *Bacillus thuringiensis*: Biology, Ecology and Safety. John Wiley & Sons, Inc. 268 p.

Gosselin,L., R. Jobidon, and L. Bernier. 1999a. Genetic variability and structure of Canadian populations of *Chondrostereum purpureum*, a potential biophytocide. Molec. Ecol., 8: 113–122.

Holt, J.S. 1992. History of identification of herbicide resistant weeds. Weed Technology, 6: 615–620.

Jarvis, W. 1995. Managing Diseases in Greenhouse Crops. American Phytopathological Press, St. Paul, Minnesota. 228 p.

Jobidon, R. 1998. Comparative efficacy of biological and chemical control of the vegetative reproduction in *Betula papyrifera* and *Prunus pensylvanica*. Biological Control, 11: 22–28.

Joung, K.-B. and J.C. Côté. 2000. A review of the environmental impacts of the microbial insecticide *Bacillus thuringiensis*. Technical Bulletin no. 29. Horticulture R&D Centre, Agriculture and Agri-Food Canada.

Molecular Analyst Version 1.12. 1997. Bio-Rad Laboratories, Hercules, CA.

Pitt, D.G., M.T. Dumas, R.E. Wall, D.G. Thompson, L. Lanteigne, W.E. Hintz, G. Sampson, and R.G. Wagner. 1999. *Chondrostereum purpureum* as a biological control agent in forest vegetation management. Part I: efficacy on speckled alder, red maple and aspen in eastern Canada. Can. J. For. Res., 29: 841–851.

Ramsfield, T.D., E.M. Becker, S.M. Rathlef, Y. Tang, T.C. Vrain, S.F. Shamoun, and W.E. Hintz. 1996. Geographical variation of *Chondrostereum purpureum* detected by polymorphisms in the ribosomal DNA. Can. J. Bot., 74: 1919–1929.

Ramsfield, T.D., S.F. Shamoun, Z.K. Punja, and W.E. Hintz. 1999. Variation in the mitochondrial DNA of the potential biological herbicide *Chondrostereum purpureum*. Can. J. Bot., 77: 1490–1498.

Rao, P.S.C. and A.G. Hornsby 2001. Behavior of Pesticides in Soils and Water. Fact Sheet SL40, University of Florida Extension, Institute of Food and Agricultural Sciences, University of Florida, Gainsville, FL. USA.

Rayner, A.D.M. and L. Boddy. 1986. Population structure and the infection biology of wood-decay fungi in living trees. Adv. Plant Pathol., 5:119–160.

Riley, B. and L. Siemsen-Newman. 2001. On the front lines: health hazards posed to pesticide applicators. P. 17–24. In: Restoring healthy school landscapes. Northwest Coalition for Alternatives to Pesticides. Eugene, OR, USA (www.pesticide.org).

Spiers, A.G. and D.H. Hopcroft. 1988. Factors affecting *Chondrostereum purpureum* infection of Salix. Eur. J. For. Pathol., 18: 257–278.

Stankis, M., C.A. Specht, H. Yang, L. Giasson, R.C. Ullrich, and C.P. Novotny. 1992. The A- alpha mating locus of *Schisophyllum commune* encodes two dissimilar multiallelic homeodomain proteins. Proc. Natl. Acad. Sci., 89:7169–7173.

Templeton, G.E., D.O. TeBeest, and R.J. Smith, Jr. 1979. Biological weed control with mycoherbicides. Annu. Rev. Phytopathol., 17: 301–310.

Wall, R.E. 1990. The fungus *Chondrostereum purpureum* as a silvicide to control stump sprouting in hardwoods. North. J. Appl. For., 7: 17–19.

Wall, R.E. 1991. Pathological effects of *Chondrostereum purpureum* in inoculated yellow birch and beech. Can. J. Pathol., 13: 81–87.

Wall, R.E. 1994. Biological control of red alder using stem treatments with the fungus *Chondrostereum purpureum*. Can. J. For. Res., 24: 1527–1530.

Wall, R.E. 1996. Pathogenicity of the bioherbicide fungus *Chondrostereum purpureum* to some trees and shrubs of Southern Vancouver Island. FRDA Report 246. Canadian Forestry Service/B.C. Ministry of Forests. Pacific Forestry Centre, Victoria, B.C.

Wall, R.E., D.E. Macey, and E. Sela. 1996. Virulence and interfertility of *Chondrostereum purpureum*. Biological Control, 7: 205–211.

Willer, H. and M. Yussefi. 2004. The World of Organic Agriculture 2004, Statistics and Emerging Trends. IFOAM Publication, 6th, revised edition, February 2004, 170 pp.

Wobschall, P. 2004. Pesticide Initiatives in Canada. A Summary of Initiatives to Establish By-laws, Laws and Policies aimed to Reduce Cosmetic Pesticide Use in Canada. Hamilton Coalition on Pesticide Issues. Hamilton, Ontario, Canada. (http://www.greenventure.on.ca/hcpi.asp?ID=89).

Zidack, N.K. and P.C. Quimby, 1998. Formulation and Application of Plant Pathogens for Biological Weed Control. pp. 371–383, *In* F.R. Hall and J.J. Menn (Eds.), Biopesticides: Use and Delivery. Methods in Biotechnology Vol. 5, Humana Press, Inc., New Jersey.

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Implications of Branch Strength Loss in Silver Maple Trees Converted from Round-over to V-trims During Electrical Line Clearance Operations

Gregory A. Dahle, Harvey A. Holt, William R. Chaney, T.M. Whalen, D.L. Cassens, R. Gazo, and R.L. McKenzie

Historically, trees growing beneath powerlines were often subjected to round-over trimming where heading cuts were used to maintain conductor clearances. An extensive flush of watersprout growth typically occurs after round-overs and trees rapidly regain their original heights. Many utilities have adopted V-trimming where the center portion of the canopy is trimmed while the exterior portion remains. Trees converted from round-overs to V-trims could develop a canopy of watersprouts growing on parent stems with a high probability of decay. This study was conducted to determine if the conversion from round-over to V-trimming predisposes trees to failure. Silver maple (*Acer saccharinum* L.) watersprouts were mechanically pulled from converted trees. In more than 20% of the sampled watersprouts the leaders broke before the watersprouts. The conversion from round-over to V-trimming appears to predispose parent stems in silver maple trees to failures. Managers should consider the long-term consequences of converting from round-over trimming to V-trimming and decide if other actions are appropriate; including the removal of trees with a history of multiple cycles of round-over trimming.

Keywords: Electrical line clearance, rights-of-way, powerline, directional pruning, heading cuts, topping, decay, tree, silver maple, strength loss

INTRODUCTION

Trees along utility rights-of-way are subjected to line clearance operations by removing portions of the tree that interfere with the conductors (Abbott, 1977; Appleton et al., 1997; Browning and Wiant, 1997; Gilman, 2002; Goodfellow et al., 1987; Harris et al., 2004). Traditionally many utilities used round-over trimming, which removes the canopy to a predetermined point, leaving a symmetrical crown below the conductors. Over the past two decades directional pruning techniques have been adopted by many utilities and V-trimming is used in trees growing directly below the conductors. V-trimming removes the interfering branches in the center of the tree and leaves the exterior portion, thus forming a "Y" shaped tree (Appleton et al., 1997; Gilman, 2002; Johnstone, 1983; Pirone et al., 1988; Shigo, 1991).

Round-over trims are initiated by a heading cut where a branch is trimmed to a point not associated with a lateral branch or bud, removing sizable portions of a tree's canopy (American National Standards Institute, 2001; Fazio, 2002; Gilman, 2002; Harris et al., 2004; International Society of Arboriculture, 2003). Furthermore, utility arboriculture draws on years of anecdotal literature and first hand knowledge suggesting that large heading cuts are harmful to a tree. In response to round-over trimming, trees often produce numerous watersprouts that are considered weak and likely to fail during a windstorm or accumulation of ice or snow. The literature also suggests that topped trees have a higher incidence of decay arising at the heading cut or from sunburn along the remaining branches, thus compounding the likelihood of failure (Costello and Geisel, 2003; Fazio, 2002; Fazio and Krumpe, 1999; Gilman, 2002; Harris et al., 2004; International Society of Arboriculture, 2003).

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Research has not investigated whether the conversion from round-over to V-trimming predisposes trees to failure. Watersprouts arising after a round-over trim are likely growing on parent stems (leader) that have a high probability of decay. If decay continues to spread, the parent stem may not be able to support the watersprouts as they increase in size. Additionally, decay may move into the watersprout, thus escalating the potentially weak nature of the watersprout.

This study was designed to determine if a difference exists in strength between normally developing lateral branches and leaders after heading cuts.

Silver maple was chosen as the subject tree as it is one of the most frequently occurring urban trees in the Midwest and is often subjected to heading cuts made during utility line clearance activities (Dahle et al., 2002; Gartner et al., 2002; Karlovich et al., 2000). In addition, silver maple has one of the lowest breaking strengths of hardwood species tested by the Forest Product Laboratory (U.S. Forest Products Laboratory, 1999).

METHODS

Sampling occurred on silver maple trees located in Tippecanoe County in central Indiana. Treatment trees had been subjected to heading cuts (round-overs), followed by an on-going conversion to V-trims during electrical line clearance operations (Fig. 1). It was estimated that these trees were subjected to 2–3 cycles (6–15 years) of V-trimming. Control trees were located at the Purdue Wildlife Area, owned and managed by the Purdue University Department of Forestry and Natural Resources, and did not appear to have a history of pruning or storm damage.

Watersprouts arising after heading cuts were mechanically tested on the treatment trees and naturally arising branches were tested on the control trees. While multiple watersprouts or branches occurred on some leaders, only one watersprout per leader was tested for failure strength (i.e., the normal stress needed to cause failure). The strength of the branches was measured by pulling on the branch until failure occurred. A rope was attached to the branch, run downward, redirected through an arborist block at the base of the tree and inserted into a winch (Fig. 2). The downward direction of the rope simulated a static load that would be applied during the build up of snow or ice.

A Dillon electronic dynamometer was hung from the branch to measure the force generated during the failure exercises. The dynamometer was capable of measuring applied forces up to 89 kilonewton (kN) with a level of accuracy of 0.02 kN. A second rope was attached to the bottom shackle on the dynamometer, run through an arborist block to a Good Rigging Control System hand winch. The rope was angled slightly in towards the base of the tree to prevent the arborist block from coming in contact with the dynamometer during the pulling exercises. The winch was secured to the pintel hook of a pick-up truck.

The dynamometer was tared and set to record the maximum applied load. The winch was cranked to apply a steady and increasing load until failure occurred.

Fig. 1. A silver maple tree converted from a round-over to a V-trim during electrical line clearance operations.

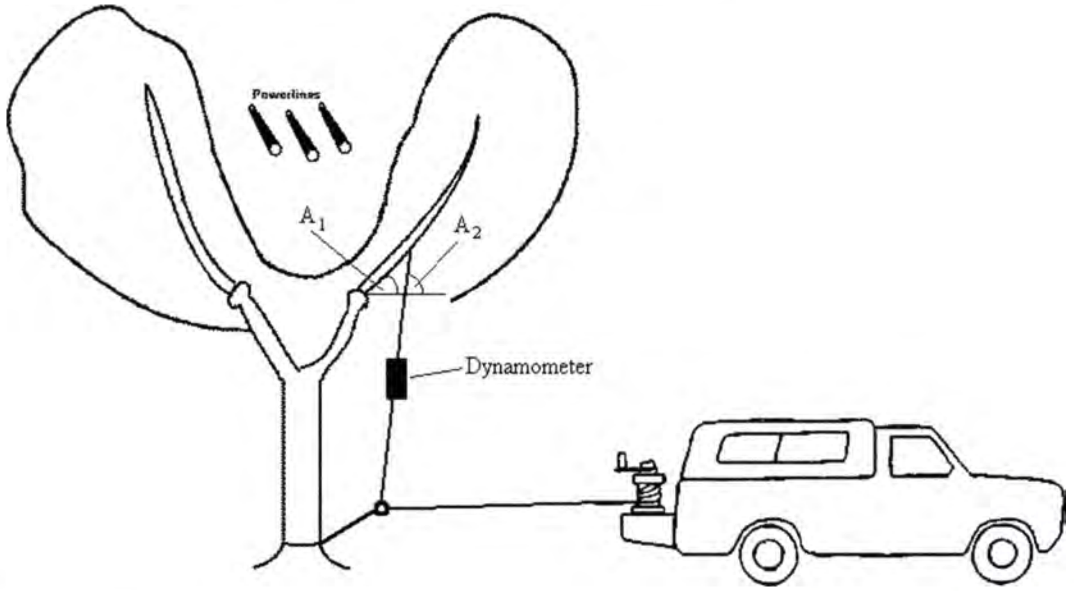

Fig. 2. Rigging for a watersprout/branch failure exercise in a silver maple tree converted from round-over to a V-trim during electrical line clearance activities. The system included a rope, dynamometer with shackles, and winch attached to a pickup truck. Angles A_1 (watersprout/branch angle) and A_2 (rope angle) are measured with 0° parallel to the ground and 90° perpendicular to the ground.

Post failure measurements included: load at failure, the location of the failure (along the branch, point of attachment, or on the leader), diameter at the point of failure, diameter of decay at failure, distance from the failure to the point of branch attachment, and moment arm (L) or the distance from the applied load to the failure.

Stress at failure (σ) was calculated using the formula for normal stress in cantilevered beams (Formula 1) (Dahle, 2004; Hibbler, 1997). Two effects were included, axial stress ($P_x/(\pi r^2)$) and bending stress ($P_yLY/(\frac{1}{4}\pi r^4)$). In this research, the axial force exerted on the branch is compressive, acting inward towards the leader. The bending force acts downward, perpendicular to the branch.

Formula 1: Normal stress equation for tensile failures along the branch or point of attachment.

$$\sigma = \frac{-P_x}{\pi r^2} + \frac{P_y(L)Y}{\frac{1}{4}\pi r^4}$$

where: L = failure moment arm, P_x = axial force, P_y = bending force, r = radius at failure, Y = distance from center point to failure.

The presence of decay was also noted for these watersprouts. After all the watersprouts were removed, the leaders were cut from the tree and sliced into 50 cm sections. The presence of external decay was recorded for each section, as well as the diameters of outside wood and internal decay for each end of the sections.

Regression analysis was used to determine linear relationships in the data. All statistical analyses were run using the SAS System version 8.2 (SAS, 2001) and significance levels were set at 5% ($\alpha = 0.05$).

RESULTS

A total of 54 branches were sampled with 28% ($n = 15$) being control branches and 72% (39) being watersprouts (Table 1). Controls failed in three locations along the branch, 7% (1) away from the point of attachment of the branch (POA) to the parent stem, 53% (8) within two diameter lengths from the POA and 33% (5) at POA. Failures in watersprouts occurred in four locations: 8% (3) away from POA, 31% (12) near the POA, 33% (13) at POA, and 21% (8) along the leader.

No significant relationship was identified between stress at failure and diameters at the point of failure for the eight failures that occurred along the leaders ($F = 0.00$, $P = 0.9867$).

Internal columns of decay were detected in 90% ($n = 62$) of the 69 leaders that were cut into 50 cm sections. External decay was present in 80% (55) of the leaders. All of the leaders with external decay contained internal decay columns.

DISCUSSION

Sprouting is a common reaction of trees to the defoliation caused by heading cuts. Branches often fail due to dynamic loading in high winds, as a result of static loading due to the accumulation of snow or ice, or a combination of both static and dynamic loading. This study simulated static loading by subjecting branches and watersprouts to bending loads by pulling downwards until failure occurred. This paper does not address dynamic loadings, such as wind.

The location of failures showed some similarities. One-third of the failures (watersprouts and control

Table 1. The percentage of failures occurring in each region for control branches and watersprouts in silver maple trees converted from round-overs to V-trims during electrical line clearance operations

Treatment	No Failure % (n)	Away POA* % (n)	POA** % (n)	Near POA*** % (n)	Leader % (n)	Total % (n)
Control	7 (1)	7 (1)	33 (5)	53 (8)	0 (0)	28 (15)
Watersprouts	8 (3)	8 (3)	33 (13)	31 (12)	21 (8)	72 (39)
Total	7 (4)	7 (4)	33 (18)	37 (20)	15 (8)	100 (54)

*Away POA = Failure occurred along the branch/watersprout and further than two diameter lengths from the point of attachment.
**POA = Failure occurred at the point of attachment of branch/watersprout to parent stem (leader).
***Near POA = Failure occurred along the branch/watersprout but within two diameter lengths from the point of attachment.

branches) were at the point of attachment (Table 1). Over one-half of the controls failed within two diameter lengths beyond the point of attachment; while only 30% of the watersprouts failed in the same way. The remaining watersprouts failed along the leader. Decay in the leaders is most likely the reason leader failures, as it appears that decay has reduced the strength of the leader until it was weaker than the watersprout growing on it.

The conversion of silver maples from round-overs to V-trims should raise concern for utility arborists. It appears these trees may pose a risk of sending large amounts of wood to the ground when leaders fail. Arborists should inspect converted trees for the presence of decay to determine the risk levels associated with these trees. In this study, decay columns were found in 90% of the leaders. These columns were externally visible in 80% of the leaders. Decay may develop directly from the heading cut, at other large pruning wounds or by sunburn, when cambial tissues die due to exposure to intense heat of the sun (Costello and Geisel, 2003). Although this data does not conclusively say that heading cuts caused the decay in the leaders, a strong trend is apparent.

IMPLICATIONS

The information presented here should aid the utility arborist in making informed decisions about the risk factors in the trees they manage. The presence of decay in leaders appears to predispose silver maple trees to failure when converted from round-over trimming to V-trimming. Utility arborists should examine their trees for the presence of decay when considering whether a tree is at risk of failure, especially when larger watersprouts are present. Managers may wish to consider the long-term consequences of converting from round-over pruning to V-pruning and decide if other actions are appropriate; including the removal of trees subjected to multiple cycles of round-overs.

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REFERENCES

Abbott, R.E. 1977. Commercial arboricultural practices in North America. Journal of Arboriculture, 3(8): 141–144.
American National Standards Institute. 2001. American National Standards Institute, Inc. A-300, Washington DC. 15 pp.
Appleton B.L., B.M. Touchette, S.C. French, and A.X. Niemiera. 1997. Developing a utility line arboretum. Journal of Arboriculture, 23(6): 219–223.
Browning, D.M. and J.V. Wiant. 1997. The economic impacts of deferring electric utility tree maintenance. Journal of Arboriculture, 23(3): 106–111.
Costello, L.R. and P.M. Geisel. 2003. Diagnosing sunburn, sunscald & thermal injury in wood plants. Tree Care Industry, 14(8): 8–10, 12, 14, 16–17.
Dahle, G.A. 2004. Strength loss and decay patterns in trees converted from round-overs to V-trims during electrical line clearance operations. Masters Thesis, Purdue University, West Lafayette Indiana. 57 pp.
Dahle, G., R. McKenzie, H. Holt. 2002. Fowler Indiana tree inventory report. Purdue University, West Lafayette, IN. 65 pp.
Fazio, J.R. 2002. Don't top trees. Tree City USA Bulleting #8. The National Arbor Day Foundation, Nebraska City, NE. 8 pp.
Fazio, J.R. and E.E. Krumpe. 1999. Underlying beliefs and attitudes about topping trees. Journal of Arboriculture, 25(4): 193–199.
Gartner, J.T., T. Treiman, and T. Frevert. 2002. Missouri urban forest-A ten year comparison. Journal of Arboriculture, 28(2): 76–83.
Gilman, E.F. 2002. An illustrated guide to pruning. Delmar. Albany, NY. 330 pp.
Goodfellow, J.W., B. Blumreich, and F. Nowacki. 1987. Tree growth response to line clearance pruning. Journal of Arboriculture, 18(8): 196–200.
Harris, R.W., J.R. Clark, and N.P. Matheny. 2004. Arboriculture, integrated management of landscape trees, shrubs, and vines. Prentice Hall, Upper Saddle River, NJ. 580 pp.
Hibbler, R.C. 1997. Mechanics of materials. Prentice Hall, Inc., Upper Saddle River, New Jersey. 854 pp.
International Society of Arboriculture. 2003. Why topping hurts trees. www.treesaregood.com/treecare/topping.asp. Tree Care Information Broucher, International Society of Arboriculture. Champaign IL. 1 pp.
Johnstone, R.A. 1983. Management techniques for utility tree maintenance. Journal of Arboriculture, 9(1): 17–20.

Karlovich, D.A., J.W. Groninger, and D.D. Close. 2000. Tree condition associated with topping in Southern Illinois communities. Journal of Arboriculture, 26(2): 87–91.

Pirone, P.P., J.R. Hartman, M.A. Sall, and T.P. Pirone. 1988. Tree maintenance. Oxford University Press, New York. 587 pp.

SAS 2001. SAS Institute Inc. Cary, NC.

Shigo, A.L. 1991. Modern arboriculture, a systems approach to the care of trees and their associates. Shigo and Trees, Associates, Durham, NH. 424 pp.

U.S. Forest Products Laboratory. 1999. Wood handbook: Wood as an engineering material. USDA, Forest Products Laboratory, Madison, WI. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch04.pdf. (Accessed 3/1/2005.)

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Exploiting Allelopathy as a Present and Future Tool in the Management of Rights-of-Way

Timothy A. Chick

The pursuit of low-growing, stable herbaceous and shrub ground covers in utility corridors has been a primary focus for researchers and managers during the past 50 years. A common assumption has been that competition for resources is the regulator of stable plant communities. That assumption may only be partially true as researchers have isolated plant chemicals that prevent seed germination and reduce tree growth in the absence of competitive factors. The role of biochemical interactions, known as allelopathy, is poorly understood in the ecological management of rights-of-way. There is an increasing body of research, however, in allied plant disciplines that may be applicable to a more complete understanding of plant community dynamics. This paper will review aspects of the science of allelopathy as they relate to integrated vegetation management. Factors such as soil texture, drainage, and allelochemical persistence may influence old-field succession, stability, and tree invasion. The development of environmentally compatible bioherbicides based on the molecular structure of allelochemicals may provide enormous opportunities for future control of vegetation. Combinations of allelochemicals may be especially effective in preventing germination and in the inhibition of tree growth. Allelochemicals as a new class of herbicide may be an answer for environmental and social concerns about current types and uses of pesticides.

Keywords: Allelopathy, allelochemicals, competition, interference, old fields, soil texture, tree invasion, mycorrhizae, herbicides, plant succession, stable plant communities, ROW

INTRODUCTION

The pursuit of stable herbaceous and shrub ground covers in utility corridors has been a primary focus for researchers and managers during the past 50 years. The high costs of mechanical and chemical management of vegetation and public pressure to reduce chemical inputs into the environment have been primary forces for understanding and utilizing ecological processes instead.

The identification of ground cover plants resistant to tree invasion as well as the development of mechanical/chemical treatment techniques to initiate and maintain these plant communities have been a boon to the utility industry. Competition for water, nutrients, light and root space generally has been the reason given as the regulator of low, stable plant communities. While these factors are most certainly operable, researchers have found plant chemicals that prevent seed germination and inhibit tree growth independent of competitive factors.

The chemical influence of one plant on another is referred to as allelopathy and is a facet of the broader field of chemical ecology. Allelopathy as a science has flourished in agriculture but, unfortunately, it has not in forestry and right-of-way (ROW) management. Allelopathy researchers in horticulture and ecology have wondered over the years why allelopathy knowledge is not incorporated into the management of rights-of-way (Putnam, 1985; 1987; Rice, 1987; 1990). This paper will address some of the challenges related to allelopathy and its role in ecological ROW management, its relevance to current practices, and its prospects for the future.

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INTERFERENCE AND ALLELOPATHY OVERVIEW

Within a community, neighboring plants may interact negatively so that germination, growth, or survival, of one or both plants are affected (Putnam and Tang, 1986). The adverse effect of a neighboring plant in an association is termed interference (Muller, 1969). The possible causes for interference include competition, which results in environmental depletion of resources needed for growth; allelopathy, which involves the addition of toxins into plant habitats; and allelomediation, which is the specific harboring of an herbivore that may selectively feed on one species, thus lending advantage to another (Szezepanski, 1977).

Since right-of-way vegetation research typically has addressed competitive effects on plant inhibition, it has rarely attempted to determine if allelopathy or allelomediation also played a role. This has led to the misuse of the term competition by many to describe interference (Putnam and Tang, 1986; Rice, 1984).

Chemicals produced by plants that influence other plants are called allelochemicals and are secondary metabolites. These low molecular weight compounds vary from simple hydrocarbons and aliphatic acids to complex polycyclic structures (Putnam and Tang, 1986). Rice (1984) has classified allelochemicals into 14 types including tannins, phenols, long-chain fatty acids, coumarins, flavanoids, and terpenoids, as well as other chemicals. Approximately 10,000 allelochemicals have been isolated and identified, while it is estimated that 400,000 may exist in nature (Swain, 1977).

Allelochemicals enter the environment by volatilization from leaves (usually in semi-arid regions); exudation from roots; leaching from leaves, fruits and twigs; and release from plant storage during senescence and decay (Horsley, 1991). Allelochemicals can adversely affect many plant processes, such as photosynthesis, cell division and elongation, membrane permeability, nutrient and water uptake, nitrification, and mycorrhizal formation (Einhellig, 1986).

Except for some volatiles that are transported through the air to a nearby plant, most allelochemicals enter and are mediated in the soil. Once there, they are subject to physical, chemical, and biological processes. Then these allelochemicals may be deactivated or changed into different chemicals that are either more or less toxic than the originally released chemical (Fisher, 1987).

HISTORICAL CONTEXT

Plant chemical interactions have been documented for over 2000 years, but only in the last century has most scientific progress been made (Rice, 1984). Beobachter (1845) showed that root "excrements" of heaths were instrumental in the death and poor vigor of ornamental trees, while Stickney and Hoy (1881) observed the "poisonous" nature of black walnut (*Juglans nigra*). Fales and Wakefield (1981) reported on a number of competition studies done in the early 1900s involving growth suppression of fruit trees from turf grasses. It was not until the 1950s, however, that the fruit tree industry began substantial work related to allelopathy and the problems in replanting peach, apple and citrus orchards (Rice, 1984). In the mid-1960s, Elroy Rice began publishing ecological studies, as well as training students at the University of Oklahoma, about allelopathy in natural systems, including old-field ecology. C.H. Muller did the same in California. A surge of progress in understanding the role of allelopathy in ecology resulted from these efforts.

It wasn't until the mid-1960s that forestry researchers began considering allelopathy as a viable factor in their work. Initially, the word allelopathy was not used in forestry. Brown (1990) and Rice (1990) indicated that their early efforts to obtain funding for research in allelopathy were frustrated by grant committee members who refused to believe allelopathy even existed. Instead, euphemisms such as "water-soluble substance" and "naturally-occurring, biologically-active compounds" were discreetly used to justify the work. By 1970, the term plant "phytotoxin" was commonly used (Chick, 1991).

Research by Brown, Fisher, and Horsley during the 1960s and 1970s dealt primarily with the problems of forest regeneration. Their work was initiated after observing poor growth of larger trees that competition theory could not explain.

Allelopathy research during the 1980s to the present has progressed in agriculture, horticulture, ecology, and chemistry. The chemistry of allelopathy was once the Achilles' heel of the science, but now modern instruments can identify allelochemicals (Putnam and Tang, 1986). Organizations such as The International Society of Allelopathy and the European Allelopathy Society, along with the Journal of Chemical Ecology, provide forums for researchers. Books by Rice (1974; 1983; 1984; 1995) as well as symposium proceedings edited by Thompson (1985), Waller (1987), and Putnam and Tang (1986) have enhanced the science.

While some forestry research into allelopathy continued after 1980, it has been sporadic and limited, especially related to forbs and ferns (Rice, 1995). Van Sambeek and his associates, however, have studied ground-cover interference of larger trees during the 1980s; Mallik has been doing the same during the 1990s to the present. Although not strictly forestry research, work by Rice and his associates have contributed immensely to an understanding of old-field ecology and early plant succession. Research by Einhellig, Putnam, and others in allied disciplines has provided valuable insight into plant mechanisms of action and chemical influences.

During the 1950s, Egler, Bramble, Byrnes, and their colleagues proposed and researched the establishment and maintenance of low, stable plant communities within electric utility rights-of-way. The cutting and spraying techniques used to produce the desired covers were not unlike traditional resource forestry regeneration approaches. Their philosophy and approach to ecological right-of-way management has become accepted practice by many progressive utility companies as a way to reduce maintenance costs and be good environmental stewards. Many researchers continue their legacy to the present. The emphasis in recent years, however, seems to be on shrub ecology and less on herbaceous covers.

During the 1982 ROW Symposium, Tillman made a presentation entitled "Potential Role of Allelopathy in ROW Vegetation Management." His purpose was "to alert the industry to the potential benefits of long-term vegetation management options which would not run afoul of EPA fact or fancy and would not increase the public ire" (Tillman, 1984). He went on to say that allelopathy was "an idea whose time has come" and was consistent with Egler and his colleagues' concept of low-growth plant communities.

Since Tillman's 1982 presentation, there seems to be increasing awareness among right-of-way professionals about the meaning of allelopathy. A position paper about ecological right-of-way management, produced in 2002 by the Environmental Energy Alliance of New York, recognizes allelopathy as a potential biological control but concedes there is only limited understanding of its function.

Unfortunately, there are few examples in the literature about corridor management that address allelopathy as an issue; however, there are some exceptions. Seven projects in the last ten years recognized the role of allelopathy as the basis for reestablishing prairie or old-field vegetation (Brown, 1995; Seguin, 1995; Smith, 1995; Farrish et al., 1997; Honig and Wieland, 1997; de Blois et al., 2002; Cain, 1997) and two studies reported on biochemical interactions (Kohli et al., 1995; Arya et al., 1995).

Probably the first right-of-way vegetation dynamics study utilizing Mueller's 1969 definition of interference was by Bramble et al. (1996) in a study entitled "Interference factors responsible for resistance of forb-grass cover types to tree invasion on an electric utility ROW." Although they did not isolate any allelochemicals with the methods they used, they made a deliberate effort to consider allelopathy as an operable factor.

Varfalvy (1995) presented a paper about a utility company plan to study various shrub extracts with suspected allelopathic potential for use against target species. Unfortunately, this exciting and very promising project was discontinued shortly after the presentation because of its high cost (Varfalvy, 2004).

CHALLENGES IN DETERMINING THE ECOLOGICAL ROLE OF ALLELOPATHY

Allelopathy may produce dramatic effects such as the death of tomatoes or 20″ diameter (dbh) white pines (*Pinus strobus*) by juglone, an allelochemical released from black walnuts (Fisher, 1978). However, allelochemical effects are usually subtle and thus more difficult to assess (Putnam and Tang, 1986). There is no simple method for recognizing the role of allelopathy in natural plant systems. Rather it is only one very complex factor in plant ecology.

The following sections present the elements of the science of allelopathy that may have relevance to right-of-way management. This "State of the Science" will address the impediments to understanding allelopathy, as well as beneficial research suggestions that may be incorporated into current ROW management practices.

Field identification

The correlation of plant symptoms and allelopathic activity has not progressed much, especially under field conditions (Chick, 1991). For example, leaf wilting may be the same whether the cause is water stress or allelochemical influence on water relations. Slow growth associated with low levels of soil nutrients may also indicate allelochemical influence on nutrient uptake. While many highly respected plant ecologists say it is virtually impossible to separate interference mechanisms in the field, Putnam (1987) encourages us to be more creative in solving this problem.

It may be necessary at present to identify understory species and their allelopathic potential, water availability, soil type, and nutrition levels before physical symptoms can be judged as allelopathic (Chick, 1991). Schlesinger and Van Sambeek (1986), knowing that tall fescue (*Festuca arundinacea*) can be allelopathic, surmised that slower than normal growth of black walnut exposed to tall fescue had to be something that competition theory couldn't explain. Further study found that top dieback occurred even with satisfactory levels of water and nutrients.

Laboratory identification

The extraction, collection and identification of allelochemicals and the detection of symptoms in the laboratory and greenhouse have improved dramatically compared to field identification techniques. Early extraction techniques usually produced only water-soluble phenolics, but better methods are capturing a greater array of allelochemicals. The introduction of mass spectroscopy, magnetic resonance, and high performance liquid chromatography have made the identification of many allelochemicals possible (Horsley, 1991). Unfortunately, many forestry studies of allelopathy have not taken advantage of modern advances in chemistry (Chick, 1991).

Bioassays are very important for demonstrating allelopathic activity (Leather and Einhellig, 1986). While many studies have used very creative ways to simulate field conditions in the greenhouse and laboratory, improper techniques can lead to incorrect suggestions of allelopathy in the field (Leather and Einhellig, 1986; Horsley, 1991). Standardized bioassay testing is recommended to correct this problem (Leather and Einhellig, 1986).

Symptoms of allelopathy in laboratory bioassays can include physiological actions as well as morphological changes. They may include changes in foliage coloration, tissue nutrient content, water potential, CO2 exchange rate, or loss of geotropic behaviors, wilting, and epinasty (Horsley, 1991).

Allelochemicals are species specific

One of the difficulties in understanding allelopathy is that allelochemicals are discriminating in what plants they affect. For example, allelochemicals from goldenrod (*Solidago spp.*) affect many tree species such as black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), and jack pine (*Pinus banksiana*) but do not affect others like yellow and black birches *(Betula alleghaniensis* and *B. lenta*) (Horsley, 1987; Brown, 1967; Fisher et al., 1978). While the presence of ground covers such as goldenrod in a right-of-way may resist invasion by many tree species, others may invade and require spot treatment.

Genetic factors may also produce variable impacts on tree survival and rate of growth. Black walnut toxins killed some strains of white birch (*Betula papyrifera*) while others survived (Gabriel, 1975). Four families of white ash (*Fraxinus americana*) were tested for resistance to tall fescue leachates with significant differences in height between families (Rink and Van Sambeek, 1987).

Seasonal variation and toxicity

Some studies of allelopathy are done by water leaching of phenols from fresh, green leaves that may produce little, if any, growth inhibition of other plants. Other studies have found that senescent and decaying fall vegetation may release toxins that were stored in or between plant cells, which are very inhibitory to other plants. Goldenrod (Fisher et al., 1978) and staghorn sumac (*Rhus typhina*) (Petranka and McPherson, 1979) are just two examples. This information is important in evaluating the methodology of interference studies.

Plant stress and toxicity

Plant stresses caused by high temperatures or by water or nutrient deficiencies also magnify allelopathic processes. Toxin-producing plants can release more allelochemicals under stress while trees that are sensitive to specific toxins may become more so when stressed (Einhellig, 1987). These effects might be so subtle and interactive with competition that they go unnoticed under field conditions. That being said, the author has observed the decline and death of a seemingly healthy white birch tree adjacent to an ailanthus (*Ailanthus altissima*) in 4–6 weeks during a protracted drought with high temperatures. Ailanthus toxins have long been reported to have allelopathic potential (Mergen, 1954).

Allelochemical persistence

The length of time that an allelochemical remains biologically active varies dramatically. Tubbs (1973) reported abiotic breakdown of sugar maple leachates in five days. Many phenols may decompose in only two weeks (Haider and Martin, 1975). Goldenrod toxins, however, were effective in inhibiting germination and growth of sugar maple, without replenishment, for over two years (Fisher et al., 1978). White birch seedling survival and growth was adversely affected for a five-year period in a nursery soil black walnut formerly occupied (Gabriel, 1975).

Edaphic influences

DeBell (1970) reported on a number of studies where phytotoxins had been shown to be associated with decreased germination or growth where soils were characterized by heavy texture, poor aeration, excessive moisture and often cool temperatures. In field studies of black walnut inter-planted with white and red pines (*Pinus resinosa*) on sandy sites in southwestern Ontario, Fisher (1978) found that 22–25-year-old pines were killed by walnut juglone on poorly-drained sites, unaffected on dry sites and moderately damaged on imperfectly-drained sites. Rietveld (1982) found similar results from a survey of 46 even-aged plantations, which included black walnut among other species. Walnut juglone also killed white pine on moderately-drained finer soils. Old fields of goldenrod, *Aster spp.*, and bracken fern (*Pteridium aquilinum*) in the Allegheny Plateau of Pennsylvania have remained stable for 80 years and have inhibited the invasion and growth of black cherry typical of the region (Horsley, 1977). The fields are on poorly drained soils along stream bottoms or high flats underlain by fragipans.

The author has also observed grass-covered, old-field sites in northwestern Lower Michigan that consist of beach sand and have remained tree free for decades. Bracken fern on sandy sites appears resistant to invasion as well; therefore, clay and poor drainage do not appear required for allelopathic responses.

The interdependence of edaphic factors is basic to understanding what's referred to as "pool size" by Hoagland and Williams (1985). Heavier-textured soils tend to have adsorptive colloids, which bond allelochemicals. The poor drainage associated with these soils results in slow leaching (Norby and Kozlowski, 1980) and probably limits microbial breakdown (Fisher, 1978). On the other hand, well-drained, coarse soils provide fewer adsorptive surfaces and solutions of allelochemicals readily leach or may be deactivated by aerobic microorganisms.

Pool size buildup

All the preceding factors have a bearing on the concentration levels of allelochemicals in the soil that are necessary for adverse impacts on seed germination and tree growth. These effects can vary over time on a particular site based on the accumulation and depletion of toxins. At present, this variability makes it very difficult to determine interference cause and effect in the field. However, for the ROW manager, it appears that identifying, developing, and maintaining old-field ground covers on clay loam or poorly-drained, sandy sites will enhance ground-cover stability.

Plant succession and allelopathy

Rice (1984) and many of his colleagues have studied the role of allelopathy in phases of the nitrogen cycle and its effects on plant succession. In particular, the processes of nitrogen fixation and nitrification seem to be susceptible to allelopathic interactions (Horsley, 1983). It appears that research in this area would be of tremendous benefit in understanding how to retard early successional pressures in rights-of-way.

Another very important way that herbaceous vegetation can limit tree growth is by interference with the symbiosis of mycorrhizal fungi and tree roots (Horsley, 1983). Allelochemicals can also disrupt root membrane permeability; thus, limiting a plant's ability to take up nutrients and water, even when these resources are present in adequate supply in the soil (Horsley, 1983). Walters and Gilmore (1976) reported tall fescue leachate effects on the uptake of phosphorus in sweetgum (*Liquidambar styraciflua*). Reindeer moss lichens (*Cladonia spp.*) also limited phosphorus uptake in jack pine (Brown and Mikola, 1974). Quackgrass (*Agropyron repens*) toxin impacts on roots and mycorrhizae have been implicated in poor growth of both corn (Buckholtz, 1971) and soybeans (Putnam and Weston, 1986).

The use of shrubs to provide species diversity and wildlife habitat has been studied and encouraged for ROW use by many researchers. Competition for light has been suggested, by some, as the basis for shrub community stability. It would seem important, however, to also examine allelopathic potential of shrubs like Nannyberry (*Viburnum lenta*), which has demonstrated stability for over 25 years (Niering and Egler, 1955). An exception to the light hypothesis was a study of lambkill (*Kalmia augustifolia*) inhibition of black spruce (*Picea mariana*) (Peterson, 1965). It was determined that the slow growth was a consequence of allelochemicals from the Kalmia damaging or destroying root cells of the spruce, and not competition.

Wittaker and Feeny (1971) pointed out that allelopathy not only can delay succession but may hasten it too. Petranka and McPherson (1979) studied the role of shining sumac (*Rhus copallina*) in the invasion of trees into prairie in north central Oklahoma. They found that sumac root exudates resulted in encroachment of sumac clones into prairie at the rate of 1.25 meters per year. Bottomland forest species were unable to invade prairie unless preceded by sumac. Upland species were able to invade directly into prairie, but the presence of sumac enhanced the invasion. Both light and chemical interference elements were identified for upland species invasion.

In the Lake States, the author has observed the invasion of green ash (*Fraxinus pennsylvanica*) directly into old fields, even those on clay-loam soils. American elm (*Ulmus americana*), which seems unaffected by most allelopathic plants, invades directly too (Chick, 1991). In addition, gray dogwood (*Cornus racemosa*) appears to be an early invader of these fields and seems to enhance the invasion of ash and elm. Staghorn sumac encroaches into old fields of goldenrod and aster in a similar manner to shining sumac in Oklahoma prairies.

Some woody plants don't seem to advance succession. The author has observed hawthorns (*Crataegus spp.*) as early invaders of old fields in southeastern Michigan where they remain for years as the lone woody species. Sassafras (*Sassafras albidum*) has been reported as an early invader of abandoned farmlands and can remain as a stable, clonal inhabitant for a century, even excluding invasion by elm (Gant and Clebsch, 1975). Black locust (*Robinia pseudoacacia*) is also allelopathically maintained in pure, stable stands (Waks, 1936). While inappropriate for use near wires, these species might be an option along ROW edges for limiting succession.

THE FUTURE

Ground cover studies

In addition to the herbaceous ground covers referred to earlier in this paper as allegedly allelopathic, De Blois et al. (2002) supplied a list of 66 grasses, sedges, forbs, and ferns that have also shown resistance to tree invasion. Putnam and Weston (1986) reported on 80 common agroecosystem weeds with allelopathic potential. Allelopathy has been suggested as a primary factor in the stability of prairie systems (Rice, 1984). Persidsky et al. (1965) suggested that prairie soils act as "storehouses" for accumulated allelochemicals that prevent the survival of ectotrophic mycorrhizae necessary for tree growth. Further study of all these plants to identify the interference mechanisms, be they competition or allelopathy, would provide extraordinary opportunities for a more complete understanding of right-of-way vegetation stability. It would also seem useful to revisit previous right-of-way studies that tested only for competition to determine if there are operable allelopathic mechanisms.

The establishment of herbaceous ground covers on power-line rights-of-way has typically been "passive," according to Brown (1995), utilizing mechanical and chemical techniques to remove undesirable trees and shrubs and allowing natural regeneration of grasses and forbs. He proposed an "active" approach, planting seed mixtures of herbaceous plants with known interference on undesirable trees, especially during corridor construction. Hydro-Quebec established ground covers that resisted invasion by four incompatible woody species (Seguin, 1995). Cain (1997) used site-specific seed mixtures of goldenrod and aster with very good success along several Canadian roadsides. Reestablishment of prairie on highway ROWs in Iowa (Smith, 1995) and on a Texas pipeline ROW (Honig and Wieland, 1997) has also achieved positive results. Weston and her colleagues at Cornell University are studying ground covers resistant to weed invasion in highway ROWs in New York (Sorin, 2003). The foregoing examples may provide models for more extensive utility ROW planting in the future, especially in the wire zone.

Impediments to progress in vegetation management

A possible reason for limited recognition of allelopathy as an interference factor in vegetation management may be single discipline research of forestry problems. Because of the complexities allelopathy presents, researchers have been encouraged to collaborate on their projects by including plant physiologists, soil scientists, biochemists, microbiologists, ecologists, and foresters, in order to address all interference elements (Rice, 1983; Putnam, 1985; Thompson, 1985; Waller, 1987).

Another reason may be the availability of effective chemicals for woody-plant control in spite of increasing governmental regulation and environmental scrutiny. And while ecological management has helped make enormous strides in addressing environmental concerns about chemical interventions, it is doubtful that the call for ever-increasing restrictions will wane. These pressures along with concerns about plant resistance to current chemicals may provide the impetus for use of allelochemicals as "natural" chemical controls of vegetation in the future. This approach is already progressing in agricultural research and practice (Rice, 1995).

Natural product development in agriculture

Putnam and Tang (1986) reported on pesticide development based on allelochemical models. They include the use of two herbicides and two plant growth regulators, primarily in Japan. Stephen Duke (1986) has been doing research on microbially produced phytotoxins as herbicides for agricultural weed control. Herbimycin A and B are examples of two microbial products used as herbicides for controlling many grass and forb species that are antagonistic to rice (Sekizawa and Takematsu, 1983). Virtually every important weed in soybeans is susceptible to microbially produced tentoxin (Duke et al., 1980). One of the potential advantages of microbial herbicides may be the availability of new sites of action for inhibiting growth (Duke, 1986).

Compared to synthetic herbicides, the cost of developing natural products is often prohibitively high and accompanied by many difficulties (Putnam and Tang, 1986; Varfalvy, 2004; Duke, 1986). Putnam and Tang (1986), however, are confident that advancements in biotechnology can overcome difficulties in creating novel herbicides. Rice (1995) is even more optimistic that natural-product herbicides could decrease the use of many expensive and often environmentally unsound herbicides in agriculture with very little additional research. He feels the U.S. Department of Agriculture should implement the available research recommendations as one of its high-priority goals.

Prospects for integrated vegetation management

Based on the progress in natural-product development in agriculture, it seems plausible to speculate about the creation of novel herbicides for use in rights-of-way management. The following example could serve as a model for research in ROW management. An interdisciplinary group of researchers at Colorado State University has conducted exciting work on the use of catechin, a root exudate of spotted knapweed (*Centaurea maculosa*), which has broad-spectrum herbicidal activity on the germination and growth of a variety of weeds (Bais et al., 2002). The authors believe that the status of catechin as a natural-plant product suggests fewer biosafety concerns, if it proves useful as an herbicide.

The research done by Hydro-Quebec in extracting ground-cover allelochems to target right-of-way tree invaders seems to be a sound approach for producing natural-product herbicides (Varfalvy, 1995). Many of the herbaceous species mentioned in this paper would be good candidates for further study as allelochem donors, especially goldenrod and quackgrass. These species produce allelochemicals called polyacetylenes, which may disrupt mycorrhizal associations and root functions that could limit nutrient uptake and growth in undesirable trees. Tree species such as ailanthus, black walnut, *Eucalyptus spp.*, sassafras and black locust also produce allelochemicals that are toxic to other trees.

While many allelochemicals may be benign or limited in their inhibition of other plants, there is excellent research, which suggests additive or synergistic effects with combinations of different toxins (Rice, 1987; Lodhi, 1975). Asplund (1969) reported a 100-fold enhancement using only two compounds simultaneously. It is conceivable that pelletized forms of toxin combinations from an array of allelopathic plants could be applied for activity against seed germination and for mycorrhizal disruption on tree roots. Current treatments of tree invaders with pellets of synthetic herbicides may be replaced with pellets of allelochemical combinations from black walnut, ailanthus and sassafras.

CONCLUSION

The management of rights-of-way has evolved tremendously during the last 50 years from manual brush cutting and full width ROW spraying to present day integrated vegetation management. Unfortunately, most research and management still presumes a competitive basis for vegetation dynamics in ROWs without regard for the overwhelming evidence in related disciplines for chemical influences in plant communities. Although allelopathy is only one factor in plant ecology, focusing exclusively on a competitive model delays a fuller understanding of plant interactions.

A first step in modifying the competition model would be to use Muller's definition of interference to describe studies that have not included testing for both competition and allelopathy. Secondly, it is important to encourage open discussion about allelopathy at forestry workshops and in college classrooms so it is not so "theoretical," even bringing in specialists from other disciplines. Lastly, research, which includes a variety of scientific disciplines, would be useful in addressing the complexities natural-product factors present. While major progress may not occur until a consortium of government, utility companies and chemical manufacturers are committed to environmentally compatible chemical usage, current integrated vegetation management and research could only benefit by incorporating allelopathy knowledge from related disciplines.

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REFERENCES

Arya, K.S., G. Parkash, and D. Rani. 1995. Allelopathic interactions of *Parthenium hysterophorus* and *Ageratum conyzoides* weeds. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. G.J. Doucet et al., eds. Hydro-Quebec. pp. 70–73.

Asplund, R.O. 1969. Some quantitative aspects of the phytotoxicity of monoterpenes. Weed Science, 17: 454–455.

Bais, H.P., T.S. Walker, F.R. Stermitz, R.A. Hufbauer, and J.M. Vivanco. 2002. Enantiomeric-dependent phytotoxic and antimicrobial activity of (+/−)-catechin. A rhizosecreted racemic mixture from spotted knapweed. Plant Physiology, 128: 1173–1179.

Beobachter, Home Correspondence. 1845. The highland pine. Gardeners Chronicle, 5: 69–70.

Bramble, W.C., W.R. Byrnes, R.J. Hutnik, and S.A. Liscinsky. 1996. Interference factors responsible for resistance of forb-grass cover types to tree invasion on an electric utility right-of-way. Journal of Arboriculture, 22: 99–105.

Brown, D. 1995. The formation of stable rights-of-way vegetation with cover crops – How do you choose which species to plant? In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. G.J. Doucet et al., eds. Hydro-Quebec. pp. 70–73.

Brown, R.T. 1967. Influence of naturally occurring compounds on germination and growth of jack pine. Ecology, 48: 542–546.

Brown, R.T. 1990. Personal communication.

Brown, R.T. and P. Mikola. 1974. The influence of fruticose soil lichens upon the mycorrhizae and seedling growth of forest trees. Acta Forestalia Fennica, 141: 1–22.

Buckholtz, K.P. 1971. The influence of allelopathy on mineral nutrition. In: Biological Interactions Among Plants. National Academy of Science, Washington, D.C. pp. 86–89.

Cain, N.P. 1997. Old field vegetation for low maintenance highway rights-of-way. In: Proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. J.R. Williams et al., eds. Elsevier Science Ltd. pp. 47–54.

Chick, T.A. 1991. Allelopathy in ornamental plant systems. MS Thesis. Michigan State University, East Lansing, MI. 213 pp.

DeBell, D.S. 1970. Phytotoxins: new problems in forestry? Journal of Forestry, 68: 335–337.

De Blois, S., J. Brisson, and A. Bouchard. 2002. Selecting herbaceous plant covers to control tree invasion in rights-of-way. In: Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. J.W. Goodrich-Mahoney et al., eds. Elsevier Science Ltd. pp. 103–110.

Duke, S.O. 1986. Microbially produced phytotoxins as herbicides-a perspective. In: The Science of Allelopathy. A.R. Putnam and C.S. Tang, eds. John Wiley and Sons. pp. 287–304.

Duke, S.O., R.N. Paul, and J.L. Wickliff. 1980. Title unspecified. Physiol. Plant, 56: 387.

Einhellig, F.A. 1986. Mechanisms and modes of action of allelochemicals. In: The Science of Allelopathy. A.R. Putnam and C.S. Tang, eds. John Wiley and Sons. pp. 171–188.

Einhellig, F.A. 1987. Interactions among allelochemicals and other stress factors of the plant environment. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. 343–357.

Environmental Energy Alliance of New York. 1991 (rev. 2002). Applications of integrated pest management to electric utility rights-of-way vegetation management in New York State. Position paper by K.T. McLoughlin, Gilboa, NY.

Fales, S.L. and R.C. Wakefield. 1981. Effects of turfgrass on the establishment of woody plants. Agronomy Journal, 73: 605–610.

Farrish, K.W., C.E. Rowell, and J.M. Dyer. 1997. Trial plantings of perennial plants on electric transmission line ROWs in north Louisiana. In: Proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. J.R. Williams et al., eds. Elsevier Science Ltd. pp. 63–66.

Fisher, R.F. 1978. Juglone inhibits pine growth under certain moisture regimes. Soil Science Society of America Journal, 42: 801–803.

Fisher, R.F. 1987. Allelopathy: a potential cause of regeneration failure. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. 176–184.

Fisher, R.F., R.A. Woods, and M.R. Glavicic. 1978. Allelopathic effects of goldenrod and aster on young sugar maple. Canadian Journal of Forest Research, 8: 1–9.

Gabriel, W.J. 1975. Allelopathic effects of black walnut on white birches. Journal of Forestry, 73: 234–237.

Gant, R.E. and E.E.C. Clebsch. 1975. The allelopathic influences of *Sassafras albidum* in old-field succession in Tennessee. Ecology, 56: 604–615.

Haider, K. and J.P. Martin. 1975. Decomposition of specifically carbon-14 labeled benzoic and cinnamic acid derivatives in soil. Soil Science Society of America, 39: 657–662.

Hoagland, R.E. and R.D. Williams. 1985. The influence of secondary plant compounds on the associations of soil microorganisms and plant roots. In: The Chemistry of Allelopathy: Biochemical Interactions Among Plants. A.C. Thompson, ed. American Chemical Society, Washington, D.C. pp. 301–325.

Honig, R.A. and G.D. Wieland. 1997. The Houston region native grass seedbank: a natural partnership between right-of-way management and conservation. In: Proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. J.R. Williams et al., eds. New Orleans, LA. pp. 83–90.

Horsley, S.B. 1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research, 7: 205–216.

Horsley, S.B. 1983. Allelopathy as a stress for urban trees. In: Proceedings of the Society of Municipal Arborists 19th Annual Meeting. R.S. Miller, ed. pp. 73–87.

Horsley, S.B. 1987. Allelopathic interference with regeneration of the Allegheny hardwood forest. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. 205–213.

Horsley, S.B. 1991. Allelopathy. In: Applications of Biological Research in Asian Agroforestry. M.E. Avery et al., eds. Winrock International, Arkansas. pp. 167–183.

Kohli, R.K., D. Singh, and D. Rani. 1995. Allelopathic potential of volatile terpenes of *Eucalyptus*. In: Proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. J.R. Williams et al., eds. Elsevier Science Ltd. pp. 102–106.

Leather, G.R. and F.A. Einhellig. 1986. Bioassays in the study of allelopathy. In: The Science of Allelopathy. A.R. Putnam and C.S. Tang, eds. John Wiley and Sons. pp. 133–146.

Lodhi, M.A.K. 1975. Allelopathic effects of hackberry in a bottomland forest community. Journal of Chemical Ecology, 1: 171–182.

Mergen, F. 1954. A toxic principle in the leaves of ailanthus. Botanical Gazette, 121: 32–36.

Muller, C.H. 1969. Allelopathy as a factor in ecological process. Vegetation, 18: 348–357.

Niering, W.A. and F.E. Egler. 1955. A shrub community of *Viburnam lentago*, stable for twenty-five years. Ecology, 36: 356–360.

Norby, R.J. and T.T. Kozlowski. 1980. Allelopathic potential of ground cover species on *Pinus resinosa* seedlings. Plant and Soil, 57: 363–374.

Persidsky, D.J., H. Loewenstein, and S.A. Wilde. 1965. Effect of extracts of prairie soils and prairie grass roots on the respiration of ectotrophic mycorrhizae. Agronomy Journal, 57: 311–312.

Peterson, E.B. 1965. Inhibition of black spruce primary roots by a water-soluble substance in *Kalmia augustifolia*. Forest Science, 11: 473–479.

Petranka, J.W. and J.K. McPherson. 1979. The role of *Rhus copallina* in the dynamics of the forest-prairie ecotone in north-central Oklahoma. Ecology, 60: 956–965.

Putnam, A.R. 1985. Allelopathic research in agriculture: past highlights and potential. In: The Chemistry of Allelopathy: Biochemical Interactions Among Plants. A.C. Thompson, ed. American Chemical Society, Washington, D.C. pp. 1–8.

Putnam, A.R. 1987. Introduction. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. xiii-xviii.

Putnam, A.R. and C.S. Tang. 1986. Allelopathy: state of the science. In: The Science of Allelopathy. A.R. Putnam and C.S. Tang, eds. John Wiley and Sons. pp. 1–22.

Putnam, A.R. and L.A. Weston. 1986. Adverse impacts of allelopathy in agricultural systems. In: The Science of Allelopathy. A.R. Putnam and C.S. Tang, eds. John Wiley and Sons. pp. 43–56.

Rice, E.L. 1974 (1984, rev.). Allelopathy. Academic Press, NY. 422 pp.

Rice, E.L. 1983. Pest Control with Nature's Chemicals. University of Oklahoma Press, Norman. 224 pp.

Rice, E.L. 1987. Allelopathy: an overview. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. 8–22.

Rice, E.L. 1990. Personal communication.

Rice, E.L. 1995. Biological Control of Weeds and Plant Diseases. University of Oklahoma Press, Norman. 439 pp.

Rietveld, W.J. 1982. The significance of allelopathy in black walnut cultural systems. Northern Nut Growers Association Annual Report, 72: 117–134.

Rink, G. and J.W. Van Sambeek. 1987. Variation among four white ash families in response to competition and allelopathy. Forest Ecology and Management, 18: 127–134.

Schlesinger, R.C. and J.W. Van Sambeek. 1986. Ground cover management can revitalize black walnut trees. Northern Journal of Applied Forestry, 3: 49–51.

Seguin, C. 1995. Hydro-Quebec research program on biological control for rights-of-way vegetation management. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. G.J. Doucet et al., eds. Hydro-Quebec. pp. 180–182.

Sekizawa, Y. and T. Takematsu. 1983. How to discover new antibiotics for herbicidal use. In: Pesticide Chemistry, Human Welfare and the Environment. Vol. 2. Natural Products. N. Takahashi et al., eds. Pergamon Press, Oxford. pp. 261–268.

Smith, D.D. 1995. Integrated roadside vegetation management: the Iowa model. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. G.J. Doucet et al., eds. Hydro-Quebec. pp. 191–193.

Sorin, M. 2003. Evaluation of the establishment of weed suppressive groundcovers along New York highways. Thesis. Cornell University, Ithaca, NY. 42 pp.

Stickney, J.S. and P.R. Hoy. 1881. Toxic action of black walnut. Translation of the Wisconsin State Horticultural Society, 11: 166–167.

Swain, T. 1977. Secondary compounds as protective agents. Annual Review of Plant Physiology, 28: 479–501.

Szezepanski, A.J. 1977. Title unspecified. Aquatic Botany, 3: 193.

Thompson, A.C. 1985. Preface. In: The Chemistry of Allelopathy: Biochemical Interactions Among Plants. A.C. Thompson, ed. American Chemical Society, Washington D.C. pp. ix-x.

Tillman, R.E. 1982. Potential role of allelopathy in ROW vegetation management. In: Proceedings of the Second International Symposium on Environmental Concerns in Rights-of-Way Management. A.F. Crabtree, ed. Mississippi State University. pp. 416–420.

Tubbs, C.H. 1973. Allelopathic relationship between yellow birch and sugar maple seedlings. Forest Science, 19: 139–145.

Varfalvy, L. 1995. Biological control of undesirable vegetation in Hydro-Quebec electric transmission rights-of-way. Development of a methodology and analytical techniques to study allelopathic compounds. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. G.J. Doucet et al., eds. Hydro-Quebec. pp. 199–202.

Varfalvy, L. 2004. Personal communication.

Waks, C. 1936. The influence of extract from *Robinia pseudoacacia* on the growth of barley. Publication Fac. University Charles, 150: 84–85.

Waller, G.R. 1987. Preface. In: Allelochemicals: Role in Agriculture and Forestry. G.R. Waller, ed. American Chemical Society, Washington, D.C. pp. xi-xii.

Walters, D.T. and A.R. Gilmore. 1976. Allelopathic effects of fescue on the growth of sweetgum. Journal of Chemical Ecology, 2: 469–479.

Whittaker, R.H. and P.P. Feeny. 1971. Allelochemics: chemical interactions between species. Science, 171: 757–770.

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Performance Standards for Assessing Vegetation Management on Rights-of-Way: Case Study of New York State DOT's Roadside Rights-of-Way Vegetation Management Program

Christopher A. Nowak, Benjamin D. Ballard, Laura K. Greninger, and Marie C. Venner

Rights-of-way vegetation managers are increasingly focused on environmental stewardship. Managers are interested in practices that will produce and demonstrate economically-sound, socially-responsible, and environmentally-sensitive decision making and operational practice. Environmental Management Systems have developed over the past decade to frame and advertise organizational efforts in environmental stewardship, but, to date; these systems have been only strategic/tactical in nature. They have not directly pertained to operations and field performance. In this paper, we present a new system for use in framing environmental stewardship activities via a set of performance standards that combine strategic, tactical and operational-level elements of vegetation management on rights-of-way. These performance standards are based on some of the process- and procedure-oriented elements from EMSs, planning elements from forestry certification systems, and a six- step operational-level model we developed for Integrated Vegetation Management. To date, we have a set of performance standards that include 10 principles and 42 criteria. We present the performance standards to stimulate critique and discussion of what environmental stewardship is for rights-of-way vegetation management.

Keywords: Environmental Management Systems, powerline corridors, stewardship, certification, principles and practices, right-of-way

INTRODUCTION

Roadside rights-of-way (ROWs) are important technical and ecological features of the landscape. Hundreds of thousands of miles of such ROWs traverse the United States, covering nearly 20,000,000 acres of land. The New York State Department of Transportation (NYSDOT) alone is responsible for 15,000 miles and 100,000 acres of roadside ROWs, including 3,000 miles of guiderails.

Because ROWs are long-linear features, they are set in the landscape to interact with a wide variety of physiographic features and geographic settings, especially water course areas associated with rivers and streams (roads have regularly been constructed in the flattest terrains associated with valleys). Socioeconomically, roads get people to where they live and work, causing them to interact with each other every day. All of these gross features and interactions heighten the importance of roads in the environment and for society.

An important maintenance activity on roads is roadside vegetation management. Vegetation is managed on roadside ROWs to meet a broad suite of objectives (Table 1). Many of these objectives are directly associated with the influence of roads on the environment: water quality protection, erosion and sedimentation control, wetland mitigation, wildlife habitat, and biodiversity. All of the objectives deal with protecting the values, benefits, and services people want from roads and roadside ROWs.

Many state DOTs are embracing environmental stewardship in their road and roadside management

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Table 1. List of objectives associated with vegetation management on roadside ROWs (after Venner, 2004)

- manage the immediate shoulder for use as a re-control zone for errant vehicles
- prevent weeds from growing into pavement
- preserve sight distances for reading signs and cornering
- offer space for utilities
- screen on-coming traffic on divided highways
- maintain slope stability, encouraging drainage of water off the roadway
- protect water quality
- protect habitat for wildlife
- preserve native plant communities
- maintain open space or green corridors
- provide for biodiversity
- produce positive aesthetics
- protect roadside areas against infestation and spread of noxious weeds
- keep vegetation back from the edge of the road to improve visibility of wildlife and reduce chance of road kill
- provide on-site area for wetland mitigation

Table 2. List of efforts made by organizations to meet environmental stewardship in transportation (after Venner, 2004)

- make wise choices based on understanding the consequences to natural, human-made, and social environments
- improve environmental conditions and the quality of life when possible, not just complying with regulations
- carefully manage environmental resources and values through partnerships among public and private entities
- elevate attitude, ethics, and behavior by individuals
- fulfill responsibilities as trustees of the environment for succeeding generations, moving towards a cost-effective and environmentally sustainable future
- integrating environmental values with partners within all transportation work as a "core business value"

endeavors (Table 2) and have used Environmental Management Systems (EMSs) to further that embrace (Venner, 2004). EMSs are generally defined as the part of the overall management system of an organization that includes organizational structure, planning activities, responsibilities, processes, procedures, practices and resources for developing, implementing, achieving, reviewing, and maintaining the corporate environmental policy (ISO, 1996). EMSs are used by companies to better manage their environmental affairs and show commitment to environmental protection (USEPA, 2002). Most EMSs are built on the "Plan, Do, Check, Act" Model. This model leads to continual improvement, based upon (after USEPA, 2002) the following:

- Planning, including identifying environmental aspects of the managed system and establishing goals (plan);
- Implementing, including training and operational control (do);
- Checking, including monitoring and corrective action (check); and
- Reviewing, including progress reviews and taking corrective action to EMS (act).

Table 3. List of needs met by using an Environmental Management System as an organizing framework (after Venner, 2004)

- desire to systematically demonstrate better environmental performance
- responsiveness to stakeholder preference
- efficient use of financial resources
- ensuring coverage of complex liability issues
- regulator's requests
- awareness that environmental stewardship leads to regulatory streamlining
- control over priorities and timelines of the EMS
- organizational culture and personal commitment
- integration of environmental systems into strategic planning processes that are already in place. Environmental management systems include elements of quality control, health and safety, finance, and human resource management
- promotion of a positive organizational image

An EMS generally is seen as a strategic, process-level model set to meet many key needs associated with environmental stewardship (Table 3) (also see Germain et al., 2002). Its direct value is based on how it guides the development of organizational structure (personnel), policy, and standard operating procedures. Organizations are left with the responsibility to make the system more structured and operationally applicable.

Recently, the State University of New York College of Environmental Science and Forestry (SUNY-ESF) and the NYSDOT formed a partnership (NYSDOT, 2002) to work on vegetation management issues associated with roadside ROWs. One aspect of that work was to develop an operational-level EMS for roadside ROWs, and frame that system as a set of performance standards that could be used to critically examine environmental performance in vegetation management. In this paper, we present our newly developed performance standards and some of the associated developmental underpinnings.

We will, as objectives for the paper:

1. Describe the need for and value of an operational-level set of performance standards;
2. Present a new Integrated Vegetation Management (IVM) model, as part of an EMS, for operational-level roadside ROW vegetation management;
3. Show how the IVM model is connected to an EMS;
4. Introduce an existing set of operational-level performance standards and application system ("green certification") from the allied field of forestry (sustainable forest management);
5. Formally propose performance standards for the ROWs vegetation management arena (combining outcomes from Objectives 2 and 4); and
6. Conclude by outlining what to do next with the performance standards.

We open our operational-level performance standards to professional scrutiny so that their credibility and utility can be improved with criticism, comment, and discussion. We feel that our work may be useful to other organizations interested in planning for, conducting, and demonstrating on-the-ground environmental stewardship. It is our hope that the model could provide impetus for a national referendum on environmental management systems, assessment, and certification of environmental stewardship in the ROWs management industries.

NEED FOR AND VALUE OF IVM PERFORMANCE STANDARDS

ROW owners who carry out responsible vegetation management that is consistent with the performance standards can obtain various benefits (Table 4). Performance standards for IVM can be used to define organizations that manage ROWs in environmentally-appropriate, socially-beneficial, and economically-viable manners (adapted from FSC, 2004b). Environmentally appropriate ROW vegetation management means maintaining biodiversity, productivity, and ecological processes. Socially beneficial management means helping local people and society at large enjoy long-term benefits. Economically viable means that vegetation management operations are structured and managed so as to be sufficiently cost effective and profitable, without generating financial profit or cost savings at the expense of ROW resources and their sustainability.

AN INTEGRATED VEGETATION MANAGEMENT SYSTEM FOR ROADSIDE RIGHTS-OF-WAY: SIX STEPS TOWARD PERFORMANCE STANDARDS

Pests on roadside ROWs are diverse. Under guiderails and near signs, the pest can be any plant that screens the guiderail or signs from the motoring public's general view. On and near the shoulders, woody plants can act as deadly fixed objects that can pose a hazard to motorists who leave the roadway. Tall-growing plants can affect sight distances. Plants of all kinds can destroy pavement directly by root growth that causes pavement breakup, or indirectly by preventing drainage of water from the roadway.

Table 4. List of various benefits that can be obtained through complete and objective application of IVM performance standards (after FSC, 2004a)

- national, regional, and state recognition that the vegetation management does not put the ROW's and affected land's natural heritage at risk and that management activities are appropriate
- the opportunity for interaction and cooperation among the various players involved in responsible vegetation management, e.g., ROW owners, social and environmental organizations, to solve problems that ROW managers face
- the assurance that future generations will enjoy the benefits of the ROW and its environment
- the assurance that vegetation management practices are responsible and will be further improved
- the assurance that ownership rights are respected
- the assurance that vegetation management is legal
- the assurance that rights of workers are respected
- the assurance that areas of natural wealth and endangered wildlife habitat are not being negatively affected

A common IVM approach to managing vegetation on roadside ROWs is to establish low-growing grasses that are maintained by regular mowing, and to control undesirable vegetation in pavement, near guiderails, road edges, and signs using a variety of chemical and mechanical treatment methods. Establishing and maintaining a managed grass community is an effective biological control of potentially hazardous or undesirable vegetation growth in a ROW (NYSDOT, undated). It may be possible to culture other low-growing plants that may provide better biological control. While an IVM approach to vegetation management does not preclude the integration of relatively coarse or broadcast methods, such as mowing, the regular blanket application of these types of treatments, without efforts to integrate other treatments in support of the development of a biological control, is not IVM. Biological control, which leads to fewer undesirable plants and results in reduced needs for treatment, is a core element of IVM (McLoughlin, 1997; 2002).

IVM has a focus on eliciting site-specific, ecosystem-sensitive, economically-sensible, and socially-responsible treatment effects that lead to refined prevention and control of target plant pests (Wagner, 1994; Nowak and Appelt, 2002; Nowak et al., 2002). A model for IVM application for ROWs that fully incorporates this focus, and frames it in a full system context, has been recently developed for the electric utility (Nowak and Ballard, 2001; Nowak and Appelt, 2002; Nowak and Ballard, 2005) and gas pipeline (Nowak et al., 2002) industries. In the IVM model, vegetation management activities for a section of ROW can be viewed as a system of steps that formalize relationships among phases of management to prevent, monitor and control undesirable plants and plant communities (Fig. 1). This system generally is applicable to a variety of lands where vegetation management occurs, though ROWs were the original, intended application (Nowak and Ballard, 2005).

As part of our partnership between SUNY-ESF and NYSDOT, we recently re-defined a six step model for application to roadside ROWs, as follows.

IVM STEP No. 1: Understanding Pest and Ecosystem Dynamics

- basic knowledge of the biology and ecology of all organisms that may be affected by management is accumulated;
- specific considerations are given to threatened, rare and endangered species, and non-indigenous invasives;

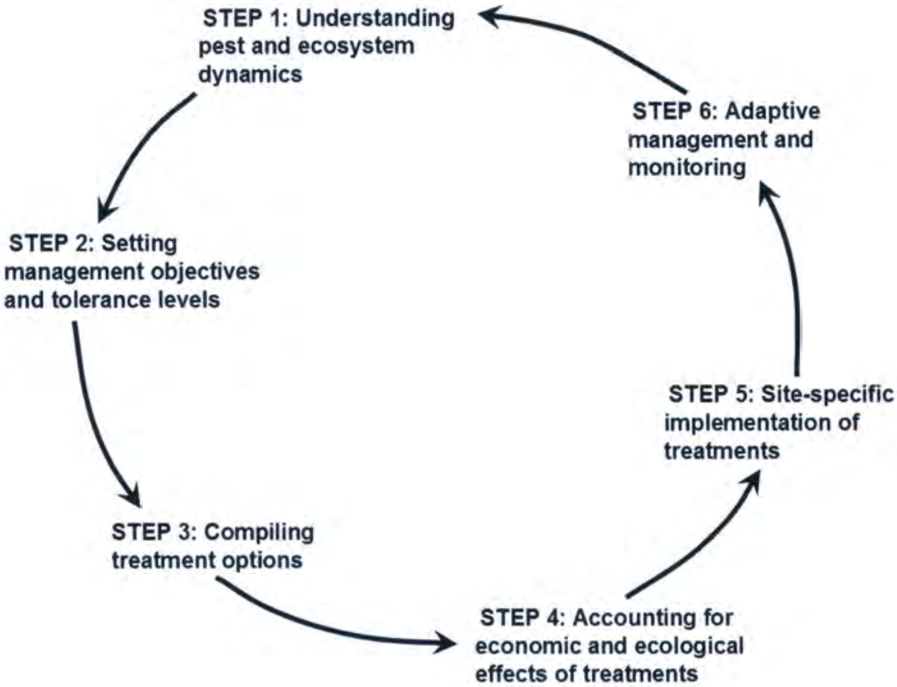

Fig. 1. A model of Integrated Vegetation Management operations showing the six steps that form a cycle of activities for a right-of-way (after Nowak and Ballard, 2005).

- research and development is used to produce new information specific to the managed system;
- education and training of key personnel is needed as new information is developed.

IVM STEP No. 2: Setting Management Objectives and Tolerance Levels

- for roadside ROW vegetation management the goal is to provide travel corridors for the efficient, effective, and safe travel of motorists, and to do so in a cost-effective, environmentally-sensitive, and socially-responsible manner;
- there are many objectives associated with such a goal, including roadway structural integrity, erosion control, storm water management, protection of habitat for desirable plants and animals, and invasive species control;
- there is much flexibility as to how managers can meet these various objectives and still achieve the overall goal;
- different zones of a roadside ROW—vegetation-free zone vs. operational zone vs. transition zone—may have different tolerances for vegetation;
- stakeholders in ROWs—anyone influenced by ROWs and their management—should be engaged in the process of developing management objectives.

IVM STEP No. 3: Compiling Treatment Options

- different treatments are needed to match variable environmental and site conditions on the ROW or to address stakeholder concerns and interests;
- vegetation treatments can be grouped into four categories: physical or mechanical, chemical, cultural, and biological; a fifth category should be included-ecological (see next bullet);
- biological treatments are usually based on culturing the natural enemy of the pest; however, when dealing with plants we often promote interference influences from competing desirable plants, which are not "natural enemies" per se, and are more like ecological control agents rather than biological;
- singular use of any one treatment through time, across all sites and conditions, is not an IVM approach;
- along any one ROW, site-specific prescriptions of treatments are needed that are sensitive to surrounding land uses, local water resources, topography, variation in vegetation conditions, and opportunities for enhancing wildlife habitat;
- minimal use of chemical treatment and preferential use of biological/ecological controls is a core concept in IVM.

IVM STEP No. 4: Accounting for Socioeconomic and Environmental Effects of Treatments

- choice of treatment must be made based on known socioeconomic and environmental impacts, including potential water, air, and noise impacts, and worker and public safety, as defined in part by public involvement;
- a useful metric for evaluation of socioeconomic and environmental effects of treatments is cost effectiveness;
- cost effectiveness is a measure of the success of a treatment in terms of economics, plant community dynamics, and related environmental considerations;

- cost of treatments include economic costs for the materials and/or labor (direct cost), but also costs associated with externalities, such as air and noise pollution (indirect cost);
- effectiveness pertains to production of desired vegetation conditions and associated benefits and values, including promotion of positive environmental externalities associated with diverse plant and animal communities, protected riparian areas and water quality, and visual attributes fashioned to minimize impacts to/or enhance aesthetics.

IVM STEP No. 5: Site-specific Implementation of Treatments

- site-specific treatments can be applied to various sections of any one ROW, and also across a ROW, e.g., vegetation-free zone vs. operational zone vs. transition zone;
- water resources, e.g., streams and wetlands, need concerted protection;
- zones associated with a roadside ROW (pavement, pavement edge, guiderail, shoulder) are set for site-specific management;
- a predetermined tolerance level (threshold) of the number and size of individual plant pests that can live in a ROW zone and not create an impact that requires immediate treatment should be defined;
- with tolerance levels, vegetation is not routinely treated, but is instead treated only as needed;
- ROWs are regularly inventoried to judge the conditions of targeted species and the need for treatment, particularly pest species that can interfere with achieving ROW objectives.

IVM STEP No. 6: Adaptive Management and Monitoring

- after the basic steps of management have been completed, and treatments have been applied, the effects of the treatments are monitored over the course of a treatment cycle;
- monitoring in an adaptive management program is valuable in assuring stakeholders that treatment effects are being gauged;
- shortfalls are adjusted for by adapting management schemes to improve IVM;
- improvements draw the circle of steps to close in the form of a self-improving cycle (Fig. 1).

An organization can apply the six steps of IVM to understand, justify, choose amongst, selectively apply, and monitor different types of treatments—mechanical, chemical, cultural, and biological/ecological (Nowak and Appelt, 2002; Nowak and Ballard, 2005).

THE IVM MODEL COMPARED WITH US EPA'S ENVIRONMENTAL MANAGEMENT SYSTEM

A tool to measure the potential effectiveness of an environmental management program—ISO 14001 (ISO, 1996)—is being used by organizations around the world to better manage their environmental affairs and to show a commitment to environmental protection. The EMS model has 17 components under five main principles (USEPA, 2002):

1. EMS Principle 1: Environmental Policy.
2. EMS Principle 2: Planning (environmental aspects; legal and other requirements; objectives and targets; environmental management program).
3. EMS Principle 3: Implementation (structure and responsibility; training, awareness, and competence; communication; EMS documentation; document control; operational control; emergency preparedness/response).
4. EMS Principle 4: Checking/Corrective Action (monitoring and measurement; nonconformance and corrective and preventive actions; records; EMS audits).
5. EMS Principle 5: Management Review.

Our IVM model for vegetation management on roadside ROWs is similar in structure to an EMS, though this was not the intent in the original IVM model construction (Nowak and Ballard, 2005). All six steps from the IVM model can be matched to one or more of the EMS steps of planning, implementing, checking, and reviewing (Table 5). The EMS Principle 1 on Environmental Policy could not be matched with any one step from the IVM model. This incongruity may be reflective of the difference between a process-oriented system (ISO 14001-based EMS) vs.

Table 5. The six steps from an Integrated Vegetation Management model (Nowak and Ballard, 2005) can be matched to one or more of the Environmental Management Systems steps of planning, implementing, checking, and reviewing (USEPA, 2002)

Environmental management system		Integrated vegetation management model
EMS Step 1: Planning	matched with	IVM Step 2: Setting management objectives and tolerance levels IVM Step 3: Compiling Treatment Options IVM Step 4: Accounting for economic and environmental effects of treatments
EMS Step 2: Implementing	matched with	IVM Step 5: Site-specific implementation of treatments
EMS Step 3: Checking	matched with	IVM Step 6: Adaptive management and monitoring
EMS Step 4: Reviewing	matched with	IVM Step 6: Adaptive management and monitoring

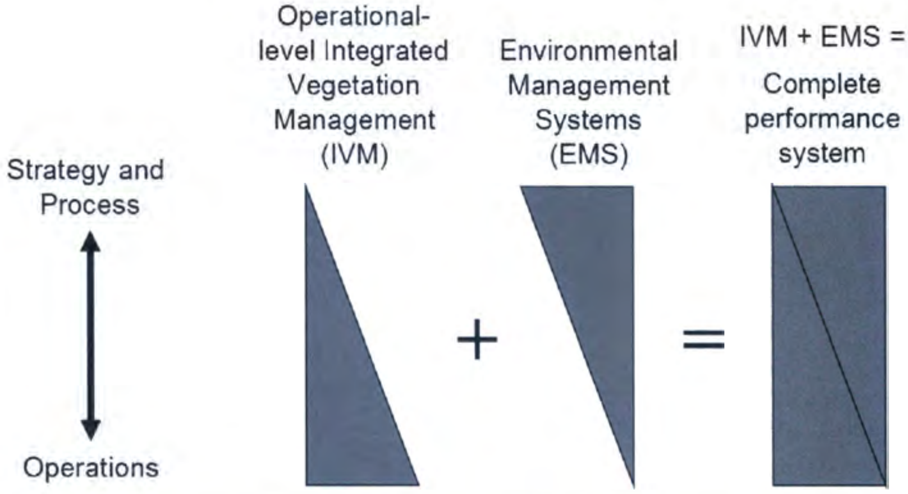

Fig. 2. Relationship of strategy and process versus operations for performance standards via Integrated Vegetation Management and Environmental Management Systems; the former emphasizes operations, the latter emphasizes strategy and process; together they represent a total system.

a performance-oriented system (IVM), with policy more on the side of process than performance. In addition, IVM is performed at an operational scale on a single section of ROW, compared to EMS, which is more in line with a strategic scale applied to management of a whole ROW system.

The notion that EMS is focused more on process than operation-level performance is important for what we are doing and why we are doing it in terms of constructing standards. In EMSs, processes are demonstrated by policy statements and documented standard operating procedures. Organizations can be certified as ISO 14001 Registered Organizations if they have developed an environmental policy statement and supporting documents, and established in-depth EMS training, and rigorous document control procedures. Documentation is required for all 17 components of an EMS, including documents on "organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining environmental policy" (Venner, 2004). An EMS sets the stage for operations and provides a framework for implementation and ensuring that feedback from operations is incorporated into relevant processes to more effectively achieve the intended environmental result. If an area of performance is found lacking during an assessment, it is important to be able to trace the shortfall back to its source, which is usually some shortfall in policy or procedure. An IVM plan or system functions as an operation-specific component of an EMS, or an EMS within a subset of the organization, designed to ensure environmentally sound and continually improving performance within vegetation management. Both EMS and IVM systems have top down (policy/leadership/funding/procedure) and bottom up (field input and knowledge application) elements. IVM employs specific operational-level performance standards.

GREEN CERTIFICATION AND SUSTAINABLE FOREST MANAGEMENT AS A MODEL

Assessments and audits of forest management organizations and their efforts at conducting environmental stewardship through sustainable forest management are becoming important and somewhat commonplace. Such assessments are used to confer a mark of excellence and identify areas needing improvement within the management program or organization.

Forestry has long-standing, mainstream assessment and certification programs, including the program associated with the Forest Stewardship Council (FSC) (www.fsc.org). The FSC is an international organization formed in 1990 to develop performance standards for assessing forest management operations. FSC also sanctions a process of using those standards via FSC-accredited third-party certifiers (SmartWood, 2004). A certification seal is awarded to forest management operations that meet the FSC principles and criteria for environmental, economic, and social standards. Certification shows the public and the forestry industry that sustainable forest management is possible, attainable and worthwhile (SmartWood, 2004).

Key elements to certification are clear principles, criteria, and indicators used by third-party auditors to assess the performance of an organization (e.g., see SmartWood at www.smartwood.org, the only U.S. FSC-approved, non-profit certification organization). Performance foci are documentation, procedures and field performance of management activities. In the FSC/SmartWood system, the standards are constructed as a series of 10 principles and associated criteria. Principles are defined as "an essential rule or element; in FSC's case, of forest stewardship" (NEWG, 2002, based on terms as defined in FSC International Principles and Criteria). The FSC defines criteria (singular criterion) as "a means of judging whether or not a Principle (of forest stewardship) has been fulfilled" (NEWG, 2002, based on terms defined in FSC International Principles and Criteria). These principles and criteria have developed progressively since 1990 based upon a global consensus of what is meant by sustainable forest management (FSC, 2004b).

The 10 FSC principles are as follows (SmartWood, 2000):

FSC Principle 1: Compliance with laws and FSC principles
- Forest management shall respect all applicable laws of the country in which they occur, and international treaties and agreements to which the country is a signatory, and comply with FSC Principles and Criteria.

FSC Principle 2: Tenure and use rights and responsibilities
- Long-term tenure and use rights to the land and forest resources shall be clearly defined, documented and legally established.

FSC Principle 3: Indigenous peoples' rights
- The legal and customary rights of indigenous peoples to own, use and manage their lands, territories, and resources shall be recognized and respected.

FSC Principle 4: Community relations and workers' rights
- Forest management operations shall maintain or enhance the long-term social and economic well being of forest workers and local communities of people.

FSC Principle 5: Benefits from the forest
- Forest management operations shall encourage the efficient use of the forest's multiple products and services to ensure economic viability and a wide range of environmental and social benefits.

FSC Principle 6: Environmental impact
- Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.

FSC Principle 7: Management plan
- A management plan—appropriate to the scale and intensity of the operations—shall be written, implemented, and kept up-to-date. The long-term objectives of management, and the means of achieving them, shall be clearly stated.

FSC Principle 8: Monitoring and assessment
- Monitoring shall be conducted—appropriate to the scale and intensity of the operations—to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.

FSC Principle 9: Maintenance of High Conservation Value Forests
- Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach.

FSC Principle 10: Plantations
- Plantations shall be planned and managed in accordance with Principles 1–9. While plantations can provide an array of social and economic benefits, and can contribute to satisfying the world's needs for forest products, they should complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests.

As part of the FSC process, region-specific standards typically are developed by a regional working group, field tested, revised, approved by the regional working group, and then submitted to the FSC for final approval/endorsement (SmartWood, 2000). While the focus of the FSC standards are not on the environment, per se, many of the principles either directly (FSC Principles 5 and 6) or indirectly (FSC Principles 1, 7, 8, 9 and 10) deal with conserving or protecting environmental resources.

Important socioeconomic and ecological principles have been developed in the FSC/SmartWood system that can be used in the ROW industry. Many of the principles are already accounted for in the IVM and EMS models presented above, but others are not (see Table 6). Three of the unmatched principles (FSC Principles 3, 9 and 10) are specific to forestry and do not appear to have a corollary in vegetation management on roadside ROWs. Four of the principles (FSC Principles 4, 5, 6 and 8) are well-matched to the IVM model, one (FSC Principle 7) partially is matched, and two are not matched at all (FSC Principles 1 and 2); these latter two may be useful in developing a complete model and related set of performance standards for vegetation management on ROWs that fully incorporates both strategic and operational elements.

PUTTING IT ALL TOGETHER: PERFORMANCE STANDARDS FOR OPERATIONAL-LEVEL ENVIRONMENTAL STEWARDSHIP ASSOCIATED WITH RIGHTS-OF-WAY VEGETATION MANAGEMENT

We have developed operational-level performance standards as an amalgamation of the steps, principles, components and criteria from the IVM model (six steps), the EMS framework (five principles) and the FSC/SmartWood standard (10 principles) (see the Appendix for a complete set of performance standards). Our standards are comprised of 10 principles and 42 criteria: six principles directly reflect the six steps of IVM, and four principles were adapted from FSC (FSC Principles 1, 2, 4, and 7) (see Table 6). All principles and criteria are collectively consistent with an EMS and offer an application of an EMS in a specific area of DOT operations where agencies have been struggling to bring about environmental improvement. In addition, the proposed performance standards have an imbedded flow and logic. The cycle of self improvement (see Fig. 1) is core to both the EMS and IVM models (Fig. 1). Principles 1 through 4 are keyed to strategic elements of performance, whereas Principles 6 through 10 are associated with operational-level performance

Table 6. Forest Stewardship Council (FSC) principles (SmartWood, 2000) can be matched with the six steps from the Integrated Vegetation Management (IVM) model (Nowak and Ballard, 2005), and collectively, they were used to develop the IVM assessment standards

FSC/SmartWood standards		Integrated vegetation management model		Assessment standards
FSC Principle 1: Compliance with laws	matched with	Nothing	applied to	Principle 1
FSC Principle 2: Tenure use rights and responsibilities	matched with	Nothing	applied to	Principle 2
FSC Principle 3: Indigenous peoples' rights	matched with	Nothing	applied to	NA
FSC Principle 4: Community relations and worker's rights	matched with	IVM Step 1: Understanding pest and ecosystem dynamics	applied to applied to	Principle 3 Principle 5
FSC Principle 5: Benefits from the forest	matched with	IVM Step 1: Understanding pest and ecosystem dynamics	applied to	Principle 5
		IVM Step 4: Accounting for economic and environmental effects of treatments	applied to	Principle 8
FSC Principle 6: Environmental impact	matched with	IVM Step 4: Accounting for economic and environmental effects of treatments	applied to	Principle 8
		IVM Step 5: Site-specific implementation of treatments	applied to	Principle 9
FSC Principle 7: Management plan	matched with	IVM Step 2: Setting management objectives and tolerance levels	applied to applied to	Principle 6 Principle 4
		IVM Step 3: Compiling Treatment Options	applied to	Principle 7
FSC Principle 8: Monitoring and assessment	matched with	IVM Step 6: Adaptive management and monitoring	applied to	Principle 10
FSC Principle 9: Maintenance of High Conservation Value Forests	matched with	Nothing	applied to	NA
FSC Principle 10: Plantations	matched with	Nothing	applied to	NA

(Fig. 3). Operational-level performance of an organization's vegetation management program/system cannot be fully assessed without including the strategic elements.

To date, the performance standards associated with the total management system (Fig. 3) have been critically examined by dozens of people from SUNY-ESF and NYSDOT. These standards were field applied/reviewed in summer 2004. Four regions of NYSDOT have been assessed with the standards: Region 4 (Rochester), Region 2 (Utica), Region 8 (Poughkeepsie), and Region 6 (Hornell). Assessments have included interdisciplinary field meetings and interviews with staff, visits to a representative sample of roadsides, and review of various documents, standard operating practices, vegetation conditions, field performances, site challenges, and vegetation management innovations. In each region, assessors from SUNY-ESF spent one-half day in the regional office with NYSDOT personnel reviewing the principles and criteria, and one full day in the field examining the state of roadside ROWs.

In general, the performance standards were well received. We have not removed any of the Principles and Criteria based on field assessment experience, but we did add new criteria related to worker compensation and rights, and investments in organization infrastructure. These additions were modeled after FSC performance standards. We did shift the position of Principle 4 (management planning) from the operational level to the strategic level after this first application so as to clarify the larger role of planning in the total system. Operational-level planning still remains in Principle 9 (site-specific implementation of treatments).

WHAT'S NEXT FOR VEGETATION MANAGEMENT PERFORMANCE STANDARDS AND ASSESSMENT OF ROW ORGANIZATIONS?

Our NYSDOT assessment will be completed by year's end. A summary of findings from the assessment currently is being developed by SUNY-ESF for each principle and criteria. A report is being developed wherein

Fig. 3. Relationship of strategic and operational principles (P) for assessing right-of-way vegetation management program performance. Operational principles (5–10) can be judged alone for performance on any one section of right-of-way (Nowak and Ballard, 2005), but when coupled with strategic principles (1–4), the total vegetation management system can be assessed.

each principle and criterion will have a series of highlighted strengths and weaknesses, sets of commendations for successes, and recommendations for program improvement.

Early on in the assessment process we learned that vegetation management on roadside ROWs is made complex by various related activities associated with siting and construction and hazard tree management. These operational areas of work need their own performance standards. For example, environmental stewardship in the transportation industry is affected by many different aspects of work, including snow and ice removal, road construction, and wetland mitigation. It is possible to have performance standards for each of these work areas. The performance standards presented in this paper are focused on within ROW vegetation management, but they could be tailored to meet other needs.

Introspective use of the performance standards by NYSDOT is laudable and will likely lead to growth by the organization as environmental stewards. Beyond that, it is our hope that the performance standards and the effort by NYSDOT will be a useful model to other vegetation management organizations, especially roadside vegetation management programs, and also other programs of vegetation management associated with electric transmission lines, gas pipelines, and railroads.

The IVM performance standards can be considered generic, in that they can be applied to a wide array of regions and organizations. It may be useful to tailor the standards by adding specific indicators that define region- or industry-specific elements of environmental stewardship. This is the process used for certification of sustainable forest management by FSC—generic, world-wide performance standards tailored for various regions in the United States.

SUNY-ESF and the NYSDOT will continue to work through the performance standards. We have learned much, and expect to learn more, and will continue to refine the standards, but their usefulness to a broader audience can only be improved with tests with other organizations. In order to improve the credibility and applicability of the IVM performance standards beyond NYSDOT and other local users, it may be necessary to have the standards sanctioned by some professional body, such as the Forest Stewardship Council for forestry or the Association of State Highway and Transportation Officials (AASHTO) for state transportation agencies.

REFERENCES

FSC (Forest Stewardship Council). 2004a. About FSC: Benefits. Website: http://www.fsc.org/fsc/about/about_fsc/benefits, accessed 07/31/2004.

FSC (Forest Stewardship Council). 2004b. About FSC: Mission. Website: http://www.fsc.org/fsc/about/about_fsc/mission, accessed 07/31/2004.

Germain, R.H., S. Harris, and V. Luzadis. 2002. Assessing environmental management systems for implementing sustainable forestry on industry forestlands. Journal of Forestry, 100(2): 12–18.

ISO (International Organization for Standardization). 1996. ISO 14001: Environmental Management Systems—Specifications with guidance for use. No. ISO 14001: 1996(E), Geneva, Switzerland.

McLoughlin, K.T. 1997. Application of integrated pest management to electric utility rights-of-way vegetation management in New York State. p. 118–126. In J.R. William, J.W. Goodrich-Mahoney, J.R. Wisniewski, and J. Wisniewski, eds. Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management, February 24–26, 1997, New Orleans, Louisiana, Elsevier Science, Inc., New York.

McLoughlin, K.T. 2002. Integrated Vegetation Management: The exploration of a concept to application. p. 29–46. In J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild, eds. Proceedings of the 7th Symposium on Environmental Concerns in Rights-of-Way Management, September 9–13, 2000, Calgary, Alberta, Canada, Elsevier Science Ltd., Kidlington, Oxford, UK.

NEWG (Northeast Region Working Group Forest Stewardship Council, U.S. Initiative). 2002. Final forest stewardship standard for the northeast region (U.S.A.), Version V7.7. PDF file available at internet website: www.fscus.org/documents/index.php, accessed on 7/31/2004.

Nowak, C.A. and B.D. Ballard. 2001. Research and development in IVM. Paper presented, Environmental Stewardship of Utility Rights-of-Way Conference, June 12–13, 2001, Albany, New York.

Nowak, C.A. and B.D. Ballard. 2005. A framework for applying Integrated Vegetation Management on rights-of-way. Journal of Arboriculture, 31(1): 28–37.

Nowak, C.A. and P. Appelt. 2002. Wildlife and Integrated Vegetation Management on electric transmission line rights-of-way. Technical Update 1005366, Electric Power Research Institute, Palo Alto, CA.

Nowak, C.A., B.D. Ballard, and P.J. Appelt (Compilers). 2002. Integrated vegetation management on gas line rights-of-way: Review of the literature. Environmental Consultants, Inc., Gas Technical Institute, Chicago, IL, and Environmental Consultants, Inc., Downers Grove, IL.

NYSDOT (New York State Department of Transportation). 2002. Alternatives to herbicide and vegetation management-research evaluation and framework. A project statement for NYSDOT's proposed research project C-02-09 (dated 9/23/02).

NYSDOT (New York State Department of Transportation). Undated, circa October 2002. New York State Department of Transportation's Integrated Vegetation Management Program: An application of Integrated Pest Management (IPM) for control of vegetation along highway rights-of-way. New York State Department of Transportation, Albany, NY.

SmartWood. 2000. Generic guidelines for assessing forest management. PDF file available on the internet website: www.rainforest-alliance.org/programs/forestry/smartwood/certification/forest-management.html, accessed on 7/31/2004.

SmartWood. 2004. SmartWood: Frequently asked questions. Internet website: www.rainforest-alliance.org/programs/forestry/smartwood/faq.html, accessed on 07/31/2004.

USEPA (U.S. Environmental Protection Agency). 2002. Internet website: www.epa.gov/ems/info/index.htm, accessed on 10/25/2002.

Venner, M. 2004. Environmental stewardship practices, procedures, and policies for highway construction and maintenance. Interim report, National Cooperative Highway Research Program, NCHRP Project 25-25 (04).

Wagner, R.G. 1994. Toward integrated forest vegetation management. Journal of Forestry, 92: 26–30.

BIOGRAPHICAL SKETCHES

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Benjamin Ballard, Research Scientist at SUNY College of Environmental Science and Forestry (SUNY-ESF) holds a BS and MS in Forest Resources Management from SUNY-ESF, and an MS in Statistics from Syracuse University. He has been involved in research at SUNY-ESF for over 10 years, and is currently responsible for the day-to-day management of various studies associated with vegetation management on powerline corridors and roadside rights-of-way. Additionally, he is a PhD candidate working on issues related to integrated vegetation management on powerline corridors, focusing on ecology and management of shrub communities.

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Marie Venner worked with two state DNRs before managing the Colorado DOT's Natural Resource Unit. She served as AASHTO's Natural Resources Expert for seven years and now consults with DOTs nationwide, in addition to performing research for AASHTO, FHWA, and the National Academy of Science's National Cooperative Highway Research Program. Her recent projects include research on advance mitigation, secondary and cumulative effects, invasive species control, and a compendium of environmental stewardship practices at transportation agencies in the U.S., Canada, Australia, New Zealand, and Europe. Marie has a B.A. in Environmental Conservation and International Affairs and Master's degrees in Regional Planning and in Public Administration.

APPENDIX

STANDARDS FOR ASSESSING PERFORMANCE OF INTEGRATED VEGETATION MANAGEMENT ON RIGHTS-OF-WAY

Principle #1: Compliance with Laws

Laws and regulations are constructs developed to protect natural resources and associated benefits and values accruable to society. IVM practitioners meet or exceed all laws, regulations, and guidelines related to vegetation management on ROWs.

1.1. Vegetation management shall respect all national, state, and local laws and regulations, for example, use of pesticides by certified applicators, Best Management Practices and other protective measures for water quality that exist within the state or other appropriate jurisdiction(s) in which the operations occur.

1.2. Vegetation management areas should be protected from unauthorized activities.

1.3. Managers and practitioners shall demonstrate a long-term commitment to adhere to the IVM Principles and Criteria:
  1. where opportunities afford, IVM Principles and Criteria are explicitly supported in the public arena,
  2. commitment is well defined via environmental policy.

Principle #2: Tenure and Use Rights and Responsibilities

Sustainable land management, including vegetation management, requires that the land be properly vested, clearly owned, and demarcated.

2.1. Clear evidence of long-term land use rights (e.g., land title or lease agreements) shall be demonstrated, including clearly identified, on-the-ground land boundaries.

2.2. Appropriate mechanisms shall be employed to resolve disputes over tenure claims and use rights:
  1. resource conflicts with adjoining landowners or other resource users are resolved or being addressed in a systematic and legal manner.

Principle #3: Community Relations and Workers' Rights

IVM shall maintain or enhance long-term social and economic well-being of vegetation management workers. A fairly compensated, respected, knowledgeable workforce is critical to long-term, sustainable vegetation management.

3.1. The rights of workers to organize and voluntarily negotiate with their employers shall be guaranteed as outlined in Conventions 87 and 98 of the International Labor Organization (ILO):
  1. managers and their contractors develop effective and culturally sensitive mechanisms to resolve disputes between workers and management.
  2. workers are free to associate with other workers for the purpose of advocating for their own employment interests.

3.2. The communities adjacent to the vegetation management area should be given opportunities for other professional services from the vegetation manager such as:
  1. representation in local civic activities, e.g., Earth Day cleanup, Arbor Day plantings, etc.
  2. contribution to public education about vegetation management practices in conjunction with schools, community colleges, and/or other providers of training and education.

3.3. Vegetation management meets or exceeds all applicable laws and regulations covering health and safety of employees, including the development and implementation of safety programs and procedures that include:
  1. well-maintained and safe machinery and equipment,
  2. use of safety equipment appropriate to each task,
  3. documentation and posting of safety procedures in the workplace,
  4. education and training,
  5. contracts with safety requirements,
  6. safety records, training reports, and certificates.

3.4. Appropriate mechanisms are employed for resolving grievances and for providing fair compensation in the case of loss or damage affecting the legal or customary rights, property, resources, or livelihood of local peoples. Measures shall be undertaken to avoid such loss or damage:
  1. managers attempt to resolve grievances and mitigate damage resulting from management activities through open communication and negotiation prior to legal action,
  2. managers and their contractors have adequate liability insurance.

3.5 Workers are fairly compensated for work, especially in wage levels as matched to the degree of skill and difficulty in job.

Principle #4: Management Planning

Documentation of philosophy, principles, procedures and practices are critical to long-term, sustainable management, as embodied by various levels of plans, including resource inventories and maps. Written plans cause managers to be held highly accountable for both successes and failures as judged against stated goals and objectives. Improvement in management practices are predicated on learning from both successes and failures.

4.1. A strategic management plan and supporting documents must be in place that provide:
  1. management policy and objectives,
  2. description of the resources to be managed (e.g., water, soil, wildlife, aesthetics) and socioeconomic conditions, and a profile of adjacent lands,

3. description of the vegetation management system, based on the ecology of the ecosystem in question and information gathered through resource inventories,
4. provisions for monitoring, including feedback mechanisms for revising procedures as appropriate to more effectively achieve objectives,
5. environmental limitations and safeguards, based on environmental assessments,
6. plans for biodiversity,
7. maps describing the resource base.

4.2. Tactical management plans are developed that report local considerations and activity plans on a year-by-year basis.

4.3. Strategic and tactical management plans shall be periodically revised to incorporate the results of monitoring or new scientific and technical information, as well as to respond to changing environmental, social, and economic circumstances.

4.4. A summary of vegetation management activities is produced annually, and both strategic and tactical management plans are revised at least every 10 years.

4.5. Workers shall receive adequate training and supervision to ensure proper implementation of the management plans.

4.6. Organization infrastructure, e.g., vegetation treatment equipment, including computers and GPS, is well developed and maintained to ensure proper implementation of the management plans.

4.7. While respecting the confidentiality of information, vegetation managers shall make publicly available a summary of primary elements of the management plan, including those listed in Criterion 4.1.

Principle #5: Understanding Pest and Ecosystem Dynamics

Knowledgeable managers and practitioners are needed. Being able to identify pests and desirable organisms in the managed system, and understanding the ramifications of management based on knowing life histories and ecosystem processes, is foundational knowledge for IVM.

5.1. Vegetation managers are knowledgeable about the managed ecosystem, especially with regard to the basic biology and ecology of all organisms in the system, and the environment in which they live.

5.2. Research and development activities are engaged to produce missing basic information on ecology of the managed ecosystem.

5.3. Vegetation managers and practitioners are provided opportunities to improve their skills and knowledge through training.

Principle #6: Setting Management Objectives and Tolerance Levels

IVM, as developed from IPM, depends upon basic elements to function as a system. Tolerance levels are one of the top elements as part of IVM, whereby vegetation is only treated if critically necessary to meet objectives. Objectives are set in context of socioeconomics and environmental desires.

6.1. Management planning, including the development of management objectives, shall incorporate the results of evaluations of social impact. Consultations shall be maintained with people and groups directly affected by management operations (see also Criterion 6.3 and Principle #4).

6.2. Tolerance levels are used to develop thresholds for when vegetation management activities are applied to control vegetation.

6.3. People and groups affected by management operations are apprised of proposed vegetation management activities and associated environmental and aesthetic effects in order to solicit their comments or concerns.

6.4. Significant concerns identified in Criteria 6.1 and 6.3 are addressed in management policies and plans (for example, management activities are modified in response to concerns, or a rationale is provided for not responding to a concern).

Principle #7. Compilation of a Broad Array of Treatment Options

IVM does not focus on the use of one treatment; instead, every ROW management situation has a treatment prescribed only after considering all possible treatments. A full "toolbox" of treatments is needed to make this consideration full and robust.

7.1. A wide variety of different mechanical, physical, chemical, cultural, and biological/ecological treatments are available for use/consideration on all sites.

7.2. New treatments are progressively evaluated and added to the vegetation management program, with emphasis on non-herbicide alternatives.

7.3. Where possible, treatments are featured that lead to, directly or indirectly, pest prevention and biological and ecological control of pests.

Principle #8: Accounting for Economic and Ecological Effects of Treatments

Cost effectiveness of treatments, in its broadest sense, is used as a basis for selecting treatments. A conservative, environmental approach is used that favors prevention. If control is needed, there is an effort to use non-synthetic pesticide alternatives and biological approaches.

8.1. Vegetation management should strive toward economic viability, while taking into account the full environmental, social, and operational costs of vegetation management. Treatment choices are made with full consideration of cost effectiveness, including a wide array of positive and negative environmental externalities, as follows:
1. water resources: perennial and ephemeral streams, wetlands, vernal pools, seeps (see also Criterion 8.5),

2. wildlife: common plants, animals and their habitats, and imperiled, threatened, and endangered species and their habitats (according to state and federal statutory listings),
3. biodiversity: efforts are made to control invasive, exotic plants; also, if state or federal listings and species databases indicate the likely presence of a rare, threatened or endangered species or plant community type, either a survey is conducted prior to management activities being carried out (to verify the species presence or absence) or the vegetation manager manages as if the species were present. If an applicable species and plant community type is determined to be present, its location is reported to the manager of the applicable database, and necessary modification are made in both the management plan and its implementation,
4. aesthetics: visual impacts of treatments are assessed.

Written guidelines shall be prepared and implemented to address management of these resources.

8.2. Management systems shall promote the development and adoption of environmentally-sensitive, non-chemical methods of pest management and strive to minimize the use of chemical pesticides. If chemicals are used, proper equipment and training shall be provided to minimize health and environmental risks (see also Criterion 1.1).

8.3. Chemicals are used to control plants only when non-chemical management practices have proven ineffective or cost prohibitive.

8.4. When chemicals are used, a section is included in the prescription that fully describes the risks and benefits of their use and the precautions that workers must employ. Records are kept to document the occurrence of pests, measures to control them, and incidences of worker exposure to chemicals.

8.5. Broken and leaking equipment and parts are repaired and removed from a right-of-way as they may contaminate a site with fuel, oil, or other chemicals; discarded parts are taken to a designated disposal facility. Equipment is not parked in riparian zones, or near groundwater supplies, where fluid can leak into them.

8.6. Chemicals, containers, and liquid or solid non-organic wastes including fuel and oil shall be disposed of in an environmentally appropriate manner at off-site locations (see also Criterion 1.1).

8.7. Use of exotic species in planting is minimized, carefully controlled, and actively monitored to avoid adverse ecological impacts. Furthermore, use of exotic plant species is contingent on peer-reviewed scientific evidence that any species in question is non-invasive and does not diminish biodiversity. If non-invasive exotic plant species are used, the location of their use is documented, and their ecological effects actively monitored.

8.8. Special cultural, ecological, economic or religious resources shall be clearly identified, recognized and protected by vegetation managers.

Principle #9: Site Specific Implementation of Treatments

ROWs should be divided into ecologically- and socio-economically-sensible management zones. These zones have vegetation management plans (prescription) that are contemporaneous in development and benchmarks for future evaluations of treatment success.

9.1. Land management units are designated within right-of-way for areas that warrant different management treatments, for example, buffers to protect water resources, conservation areas, and vegetative communities that may cause a change in successional directions or rate.

9.2. Written prescriptions (or, operational plans) are used to describe/prescribe treatments on a land management unit basis, and justify treatment choices using ecological, socioeconomic, and administrative opportunities and constraints. Prescriptions should include:
1. land management unit designation,
2. description of current vegetation and environmental conditions,
3. desired future conditions,
4. definition of treatment,
5. justifications for treatment based on tolerance thresholds (also see Principle #6) and ecological, environmental, socioeconomic, and administrative considerations,
6. site-specific maps that detail land management units, and show important cultural and environmental features.

9.3. Prescriptions and the decision to treat are based on contemporary inventories of vegetation and environmental conditions.

Principle #10: Adaptive Management and Monitoring

IVM has a self-improvement mechanism: vegetation management objectives are used to evaluate whether management outcomes are acceptable. Monitoring is the collection of appropriate data to judge successes and failures of vegetation management. Monitoring procedures should be consistent and replicable over time to allow comparison of results and assessment of change.

10.1. Implementation of the strategic and tactical management plans are periodically monitored to assess:
1. the degree to which the management vision, goals and objectives have been achieved,
2. deviations from the plan,
3. unexpected effects of management activities and other disturbances,

4. social and environmental effects of management.

10.2. Vegetation management should include the research and data collection needed to monitor, at a minimum, the following indicators:
1. condition of the right-of-way,
2. composition and changes in the flora and fauna,
3. environmental and social impacts of operations,
4. chemical use,
5. cost, productivity, effectiveness and efficiency of vegetation management.

10.3. Results of monitoring shall be incorporated into the implementation and revision of the management plan.

10.4. While respecting the confidentially of information, vegetation managers shall make publicly available a summary of the results of monitoring indicators, including those listed in 10.1.

The Application and Business Benefits of Aerial Laser Survey Techniques Used in the Management of Vegetation Encroachment within Transmission Rights-of-Way

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The National Grid Transco Group (NGT) and its predecessor companies have long supported the use of new and emerging technologies, particularly when it can be demonstrated that significant business or process improvements will be the end result. Since 1997/98 the ongoing development of this technology has been the responsibility of National Grid Transco subsidiary Network Mapping Limited. Some of the key work done by Network Mapping over the last 4–7 years, has been in relation to the development of best practice in the acquisition of ALS data; in demonstrating the accuracy of the data obtained from ALS surveys; in the quality management of the accuracy process; and in the practical use of the data for power system applications. This paper describes how this best practice (for the UK transmission system) was modified to reflect the specific and sometimes very different requirements and challenges of a US Right-of-Way (ROW)-based power transmission network. Vegetation management is a key area where the use of ALS data can provide significant business benefits to the asset manager. This paper looks at the benefits already enjoyed by the NGT UK Transmission business and details how these techniques are being developed to provide similar business and process improvements on the NGT US network.

Keywords: LIDAR, aerial laser survey, clearance, right-of-way, vegetation

NATIONAL GRID TRANSCO AND AERIAL LASER SURVEY

Aerial Laser Survey (ALS) or LIDAR (Light Detection and Ranging) services have been available for a number of years and the application of these techniques to Power Systems has progressed accordingly.

National Grid Transco (NGT) has been committed to the development of ALS techniques to deliver real business benefits to power system owners since 1997. This commitment, coupled with the ongoing technological advances in the survey equipment used and the accuracy of the survey techniques employed, has resulted in the development of a capability to generate detailed engineering models of the transmission lines, towers and their immediate surroundings.

These data, when utilized effectively, provides power system managers with the information they require to allow informed decisions to be made on a range of power system applications. This paper examines the application and use of data acquired using ALS techniques for management of vegetation encroachment on transmission rights-of-way.

ALS – THE TECHNOLOGY EMPLOYED

Almost all ALS/LIDAR systems are based on the same technology: laser radar. This works a lot like ordinary radar, except that LIDAR systems send out narrow pulses or beams of light rather than broad radio waves. A receiver system times, counts and processes the returning light. Laser radar depends on knowing the speed of light, approximately 0.3 meters per nanosecond. Using this constant, we can calculate how far a

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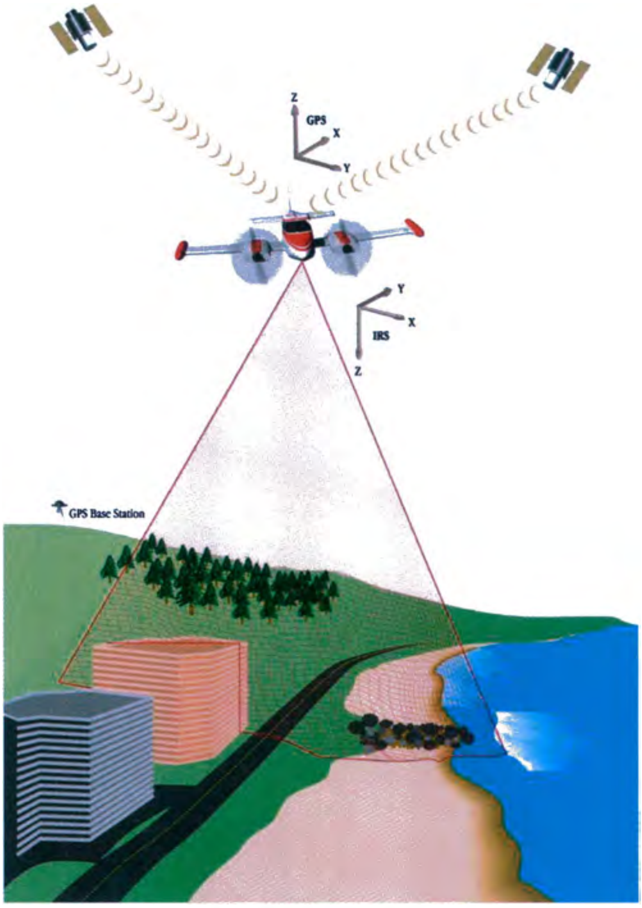

Fig. 1. Illustration of ALS techniques for corridor mapping.

returning light photon has traveled to and from an object.

The LIDAR system, used by Network Mapping, 'fires' 50,000 pulses of light per second. These pulses are spread by a rotating mirror by up to ±20 degrees from vertical, ensuring a swath or corridor coverage for the system. The technology within the LIDAR system combines the laser point information with very accurate Global Positioning System (GPS) measurements of the aircraft position in space. When processed with the ground GPS measurements for the same period, the output is a 'cloud' of very accurate measurements off all ground and above-ground objects within the survey swath. Figure 1 illustrates this technique.

ALS – DATA ACCURACY

A key component of ALS data acquisition is the ground-based GPS recording station, a number of which will be placed along the route of the power line corridor at regular intervals.

The ground GPS data is combined with the aerial GPS data to provide individual laser point accuracy to within +/−15 cm. To determine actual laser point accuracy, with any demonstrable degree of confidence, within this range requires additional effort on the behalf of the ALS service provider.

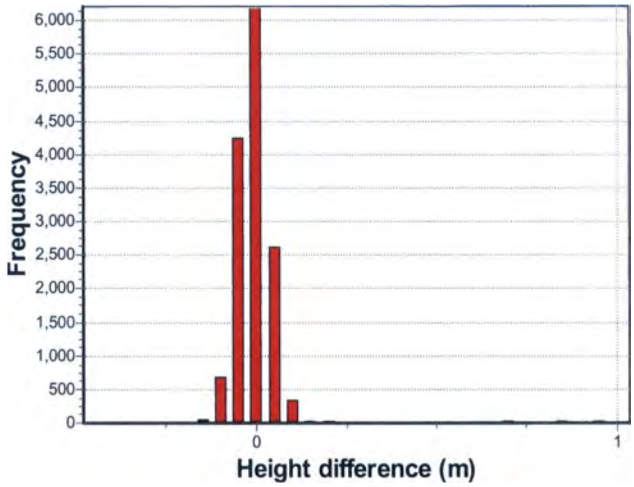

Fig. 2. Ground truthing analysis results (USA).

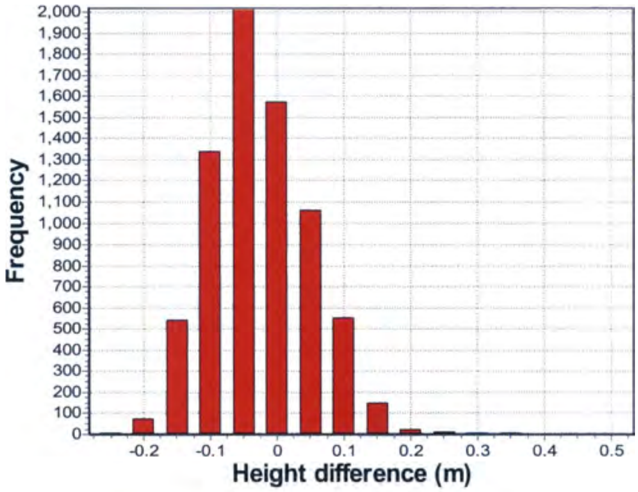

Fig. 3. Ground truthing analysis results (UK).

Network Mapping Limited (NML) confirms laser point accuracy by implementing a program of Ground Truthing Studies during each data acquisition project. Ground truthing requires the pre-survey selection of a number of ground areas, within the data acquisition swath of the planned aerial survey. During the survey, the GPS ground station surveyor records the ground profile of the selected area, accurate to within +/−0.5 cm. The laser point positions from the aerial survey and the ground survey are compared and a table of results produced.

Figure 2 shows the results obtained from a ground truthing exercise carried out in Northeast US during 2002. This survey was carried out in an area, which includes dense vegetation and sharply irregular terrain. In this particular case, the analysis of 7,355 laser points showed a mean absolute accuracy of −2.6 cm, with standard deviation of 0.077, for all raw laser points.

In contrast, Fig. 3 shows the results obtained from a survey in the UK, during 2002. This survey was carried out in much more uniform terrain and open countryside.

The mean absolute accuracy measured was −0.2 cm, with a standard deviation of 0.081 over a sample of 14,278 ground points.

These results, when analyzed with others taken over a range of projects totaling 5,000 circuit kilometers, during 2002, demonstrate that it is possible to define regular features (e.g. roads, open countryside, power line catenaries, and tower cross-arm attachment points) to a much greater absolute accuracy than that suggested by a single laser point.

The results obtained show that the position of key power line components (attachment points and catenary position) can be obtained using ALS techniques to accuracies of +/−1 cm. Ground position, depending upon the terrain type, can be defined to an accuracy of +/−0.2 cm to +/−9 cm.

The continuous assessment of ALS data accuracy provided by adopting this methodology ensures that both client and ALS service provider can provide documented evidence to support the accuracy claim for any work carried out using the survey data-set. This process is a significant step forward in the documentation of ALS performance against traditional client accuracy specification requirements.

ALS – FROM LASER POINT DATA TO PLS-CADD® MODEL

ALS data, in its raw format, has no practical use for a power system asset owner, operator or maintainer. There are a number of processing steps required to convert this data into useful engineering information.

The ALS data set, in this raw format (see Fig. 4), is simply a list of points, positioned in space (to an accuracy limit – see above). Each point represents the X, Y, Z co-ordinate of a laser reflection from an object within the swath of the aerial survey.

To use this mass of data (approximately 6 million measurements per linear mile) in a practical manner, each measurement (or point) needs to be 'coded' to represent a specific object or feature. Feature codes are identifying numeric descriptors of each object type, within the PLS-CADD® feature code table the clearance is assigned (see Table 1 for extract of feature code table).

In addition to coding the ALS data, Network Mapping will create models of the towers used in the construction of the line; model the physical characteristics of the conductor/s used; and combine these data sets with laser point data and digital imagery of the route within a PLS-CADD® model.

To accurately model the conductors, Network Mapping calculates the conductor temperature at the time of the survey (using conductor specifications and load data provided by the client and meteorological data collected during the survey) by using either IEEE or CIGRE protocols, depending upon the client specification. This ensures that network mapping can accurately model the performance of the conductors under all load/temperature conditions.

The data sets used to populate the PLS-CADD® model can also be used in a range of other power system applications to provide real business benefits to the power system engineer.

Table 1. Extract of feature code table

Feature code number	Feature code
100	Tower Bases As Erected
113	Pole With Light
115	Structure Geometry
118	All Ground Points
119	Profile Conductor Center
120	Profile Conductor Left
121	Profile Conductor Right
122	Profile ROW Left
123	Profile Centerline Alignment
124	Profile ROW Right

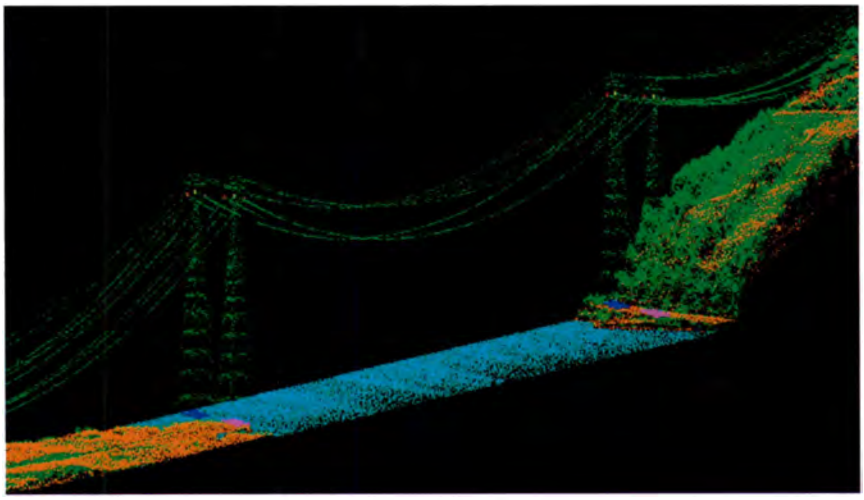

Fig. 4. ALS data (power line corridor).

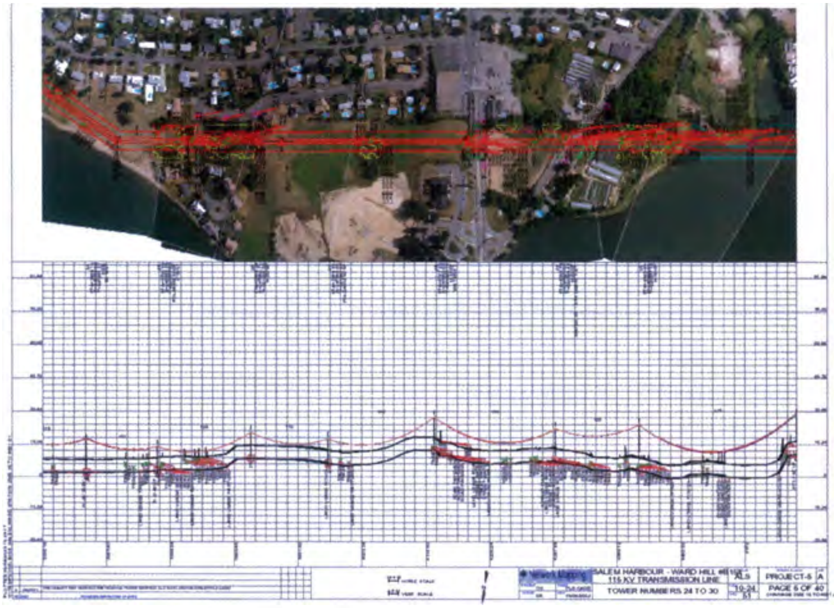

Fig. 5. PLS-CADD® model – plan and profile view.

POWER LINE APPLICATIONS OF ALS IN NGT

The application of ALS data, within the NGT-UK transmission business has been a continually developing process, over a period of 7 years.

The initial business driver for the use of this technology was the updating of asset engineering records, some up to 40 years old, often in poor condition, and incompatible with modern IT systems. Replacement of all existing overhead line (OHL) profiles and line schedules was completed in 3 stages between 2000 and 2003. The new records are in electronic format, readily accessible by people with access to the NGT IT infrastructure.

As the delivery of the records improvement program progressed, it became clear that the source data set was highly flexible and could easily be used in a number of different applications – each delivering benefits to NGT.

System operator applications

- Meteorological Office Ratings Enhancement (MORE).
  Utilization of ALS data and Digital Photo-mosaic to analyze line routes for opportunities to apply weather-related rating enhancements.

Asset management applications

- Thermal Uprating of overhead lines (OHLs).
  Modelling of route under a range of load conditions.
  Specification of improvements needed to achieve uprating.
  Re-analysis of route following improvements.
- Preliminary Engineering.
  Provision of OHL source data packs for pre-tender issue to contractors.
  Development of OHL models.
- New OHL Design and Construction.
  Survey of new line route and surrounding area to develop digital terrain models.
  Optimization of OHL routing and subsequent modification during project licensing proceedings.
  Identification of construction equipment set-up locations for construction planning.
  Re-survey of completed line to provide 'as built' records.
- OHL Refurbishment.
  Modelling of route using existing towers and different conductor options.
  Identification and correction of pre-existing clearance infringements at rated operating temperature.
  Specification of work for bidding purposes.
  Identification of construction equipment set-up locations for contractors.
  Provision of 'as built' records, following refurbishment.
- Health and Safety (HandS).
  Digital photo mosaic of route used in support of HandS plan assessments for construction activities.

ALS AS A VEGETATION MANAGEMENT TOOL

The application of ALS data to assist in the management of vegetation encroachment has been the subject of a development project between Network Mapping, NGT-UK Transmission overhead line maintenance personnel and NGT-UK's vegetation management contractors. The development work has considered two different applications, vegetation encroachment from below conductors and proximity tree analysis. Each of these applications as detailed below use ALS data and PLS-CADD® models, which represent the power system under its maximum power rating. This is only possible because of the work carried out to model the conductors and underlying ground features, which allows Network Mapping to analyze the power system under any specific load conditions. By using the worst case scenario (maximum rating), it is possible to consider the effects of vegetation growth on the power system under conditions that would not be easily estimated on site by the OHL maintenance teams.

Proximity tree analysis

The aim of this development activity was to establish if ALS data could be used to identify trees that, under very specific circumstances, could be a danger to the power system, either through their current size and position or if they were to fall towards the power lines. This work focused on providing information to the OHL maintenance teams and vegetation management contractors in a format that could easily be read and understood on site. It was also necessary to give consideration to the amount of time and effort spent in the analysis and identification of these trees.

Using the above criteria as guidance, two different types of analyses were developed – one using a system clearance report as its basis and the second using the PLS-CADD® model as its basis.

The clearance report (see Table 2) is a document prepared for NGT that identifies clearances to all objects within the span of an OHL and identifies if there are any clearance infringements. The development team was able to use this data to generate an additional report that identified trees, outside the immediate swath of the power line, which could be considered a potential hazard (see Table 3).

The information contained within the clearance study is necessarily limited, resulting in an analysis that identifies potential problems. In this example 72 trees were identified and the report provided the exact position of each tree, allowing the field teams to conduct on-site analysis. The advantage of this approach is that it requires minimal engineering effort and can quickly be issued to the field teams for analysis. The disadvantage of this approach is that more effort and decision-making is passed onto the field teams.

When the same analysis was conducted using routines available within PLS-CADD® only 15 trees were identified in the analysis as being a potential hazard (see Table 4). The significant difference here was that the analysis, while 100% accurate, required a significantly greater application of engineering resource to produce and a correspondingly lower application of resource for the field teams.

Table 2. Extract of system clearance report for a UK power line

Clearance Table : 4ZJ Route (Right Bottom Phase)

Span	Design Sag at 65°C	Sag at 65°C	Actual Clearance at 65°C	Crossings	Distance from Prev	Offset	Land Type	Span (m)	Eq.Span (m)	Marginal clearance <1m	Marginal clearance <500mm	Infringement
4ZJ73	16.56	16.46	11.78	GROUND	223.04	-8.28	Arable	417.73				
			3.77	TREE	147.44	-7.16						+
			12.89	TREE	393.48	-7.28						
			25.42	ROAD	398.03	-11.50						
			19.42	TREE	402.55	-11.08						
4ZJ74	14.25	14.17	12.50	GROUND	229.13	-7.41	Rough/ Ride	387.53				
			10.89	TREE	208.97	-18.27						
4ZJ75	11.87	11.91	8.16	GROUND	197.16	-8.52	Rough/ Ride	353.51		+		
			6.23	TREE	243.26	-12.27				+		
			13.08	TREE	293.56	-18.60						
4ZJ76	17.22	17.65	8.82	GROUND	198.50	-9.00	Rough/ Bushes/ Pasture	426.43				
			12.59	TREE	98.82	-18.53						
			3.82	HEDGE	182.67	-9.81						+
			8.82	ROAD A288	198.50	-9.00				+		
			8.61	TREE	200.65	-5.28						
			5.27	TREE	215.42	-13.44						+
			15.94	TREE	425.25	-18.82						
4ZJ77	10.59	10.81	8.02	GROUND	262.87	-9.07	Pasture/ Rough	334.61			+	
			5.28	TREE	139.65	-12.71						+
			4.69	TREE	249.31	-7.44						+
			9.99	TREE	326.46	-18.63						
4ZJ78	5.94	6.05	9.22	GROUND	129.80	-8.60	Rough	250.39				
			5.57	TREE	89.80	-8.99					+	
4ZJ79	10.67	10.89	9.99	GROUND	108.88	-9.13	Rough	335.81	372.31			
			4.67	TREE	97.62	-6.89						+
			7.59	TREE	168.02	-4.89						
4ZJ80	14.73	15.03	10.71	GROUND	324.56	-7.36	Pasture/ Rough	394.52				
			7.55	TREE	204.82	-4.05						
			12.73	HEDGE	386.75	-9.94						
4ZJ81	15.65	15.95	8.75	GROUND	203.58	-7.55	Pasture/ Bushes	406.38				
			10.39	HEDGE	19.93	-0.42						
			2.82	TREE	119.32	-9.10						+
			6.27	TREE	240.69	-12.11				+		
			7.76	TREE	254.13	-16.27						

Table 3. Extract of system clearance report with proximity/falling tree analysis

Span	Design Sag at 50°C	Sag at 50°C	Actual Clearance at 50°C	Crossings	Distance from Prev	Offset	Land Type	Span (m)	Eq.Span (m)	Marginal clearance <1m	Marginal clearance <500mm	Infringe-ment	Falling Trees
sub- 4VF1													
4VF1- 4VF2	9.79	9.30	11.10	Ground	121.92	8.68	Wood / Arable	325.52	337.33				
			5.20	TREE	33.23	10.11						*	
4VF2- 4VF3	11.19	10.91	11.48	Ground	164.45	8.56	Arable	348.01					
4VF3- 4VF4	12.19	11.88	9.49	Ground	180.70	8.02	Pasture / Road / Arable	363.10	335.41				
			26.54	TREE	119.61	-18.62							1.00
			30.91	BUILDING	178.52	-22.86							
			10.27	TREE	307.42	10.61							
			18.30	ROAD	315.39	11.07							
			19.50	TREE	339.50	12.74							
4VF4- 4VF5	15.77	15.16	12.31	Ground	141.12	8.19	Arable / Road / Gold Course / Pasture	412.91					
			10.31	HEDGE	137.90	4.90							
			12.78	ROAD	157.69	9.93							
			20.73	HEDGE	312.45	4.14							
			24.09	ROAD	319.39	5.69							
4VF5- 4VF6	4.88	4.69	18.78	Ground	127.16	8.14	Pasture	229.78					
4VF6- 4VF7	9.58	9.21	10.02	Ground	181.98	7.93	Arable	321.87					
			18.35	TRACK	299.81	12.52							
4VF7- 4VF8	9.73	9.36	15.04	Ground	83.17	6.43	Arable / Pasture / Road	324.44					
			13.74	HEDGE	127.53	6.56							
			13.20	TREE	148.68	16.41							
			18.27	ROAD	170.70	12.11							
			13.48	HEDGE	175.29	6.39							
			9.14	TREE	185.12	8.28							
			14.35	HEDGE	186.10	18.09							1.00
			18.94	FENCE	187.64	20.53							
			14.74	HEDGE	193.44	19.17							1.00
4VF8- 4VF9	6.10	5.97	11.39	Ground	112.69	7.43	Arable	255.79					
			19.01	TREE	11.71	2.63							
			17.86	TREE	19.81	5.61							
			8.06	11 kV Line	197.49	8.53							
			12.21	HEDGE	197.61	14.14							
4VF9- 4VF10	16.21	15.91	11.94	Ground	254.09	7.40	Arable	425.40					
			15.61	HEDGE	75.75	13.08							
			19.18	ROAD	81.13	8.80							
			9.13	TREE	90.33	12.18							
			15.07	TREE	99.41	1.28							
			10.91	BUILDING	110.67	9.44							
			11.41	BUILDING	111.42	9.71							
			7.90	HEDGE	115.26	4.40							
			7.90	TREE	115.26	4.40							
			8.27	TREE	129.87	5.23				*			
			12.68	HEDGE	154.79	13.28							
			9.39	BUILDING	164.60	6.98							
			8.96	HEDGE	173.82	8.21							
			18.32	TRACK	209.08	20.53							
			3.99	TREE	211.00	9.00						*	
			11.95	TREE	226.37	17.39							

Following this trial, it was decided that the most economic approach for the majority of circumstances, would be to use the clearance schedule analysis. The advantages of this simplified approach, in the UK, outweigh the benefits that the more detailed PLS-CADD® analysis provides.

The UK field analysis work is easily combined with other OHL maintenance tasks and with the regular vegetation management works – mainly completed by external contracting organizations.

It was noted that the PLS-CADD® analysis would provide significant advantages where access to sites was either restricted or very difficult to achieve on a regular basis. Work teams could then be tasked to target only specific pre-identified problems, minimizing the site work element of the project.

Vegetation encroachment on power lines

The objective of this development project was to establish if it was possible to identify and quantify the amount of vegetation management work required to meet statutory clearances below a power line. As before, a key objective of this process was to ensure that the information provided was of value to the OHL field teams.

To meet these requirements, the OHL route, built from processed ALS data was overlaid on geo-referenced digital imagery. All objects within the survey

Table 4. Extract of PLS-CADD® proximity/falling tree analysis report

Vegetation analysis report

This report includes only survey points with offsets from centerline less than 100 (m) that also have a horizontal distance from a wire of less than 50 (m).
Analysis includes only the following feature codes: 150, 151, 152, 153, 154, 155, 156, 157, 158.
Falling tree analysis assuming a root ball radius of 15.0% of tree height and a grow-in allowance of 3.10 (m).

From structure #	To structure #	Station (m)	Offset (m)	*X* (m)	*Y* (m)	*Z* (m)	Total clearance (m)	Vertical violation (m)	Violation type	Ground elevation (m)
104	105	35788.44	−4.91	498327.33	124841.06	43.51	4.44	0.27	FALLING TREE IMPACT	Tree Hgt. = 8.11
115	116	39904.15	−12.14	502284.58	125599.99	15.76	4.65	0.71	FALLING TREE IMPACT	Tree Hgt. = 12.24
125	124	42634.59	11.94	504634.30	126967.18	27.32	4.30	0.41	FALLING TREE IMPACT	Tree Hgt. = 6.83
146	147	50182.88	12.63	511555.39	125171.06	25.11	5.21	0.04	FALLING TREE IMPACT	Tree Hgt. = 7.42

Fig. 6. Photo-mosaic of route with critical vegetation identified.

swath were classified and the conductors modeled at maximum temperature. The 3-D co-ordinates of the points, representing those trees closest to conductors were then identified. The next step was to determine the distance from the conductors (at rated temperature) to each vegetation point. These points were colored, based on their proximity to the conductors and client requirements for clearances.

These points are used to generate polygons, showing the areas of vegetation to be managed. In Fig. 6, the polygons (in red) outlining the area of woods to be cut, based on the client clearance requirements, are superimposed on the digital photo-mosaic of the route. This, combined with the data in the clearance schedule (see Table 5), gives sufficient guidance to the field teams to manage the vegetation encroachment in this area.

THE NEXT STEPS

The development project works, outlined above, have been carried out on the NGT transmission system in

Table 5. Extract of clearance study with quantification of vegetation to be managed

Span	Sag	Actual Clearance	Crossings	Distance from Prev	Offset (m)	Area for tree cutting	Span (m)	Eq.Span (m)	Marginal clearance <1m	Marginal clearance <500mm	Infringement
234-235	4.55	7.12	Ground	56.00	3.16		117.28				
		5.13	Tree	4.78	6.04					+	
		9.75	Tree	9.27	-3.48						
		4.32	Tree	11.81	2.48						+
		10.42	Tree	16.97	-4.99						
		5.18	Tree	17.51	2.74					+	
		14.48	Tree	18.56	-9.30	815M^2					
		13.03	Tree	31.44	-8.34						
		13.99	Tree	37.55	-9.78						
		3.48	Trees	57.56	6.75						+
		4.08	Trees	78.08	6.95						+
		6.76	Trees	81.90	0.33						
		4.33	Trees	98.04	5.65						+
235-236	3.78	7.59	Ground	62.02	3.26		104.43	104.46			
		9.39	Trees	23.27	-1.65						
		5.83	Tree	35.66	0.62				+		
		9.53	Tree	51.16	-4.71						
		4.23	Tree	55.38	4.14	681M^2					+
		3.47	Tree	67.68	2.38						+
		7.34	Tree	78.78	-1.54						
		11.92	Tree	91.84	-5.87						
236-237	3.05	8.60	Ground	43.04	2.12		94.02				
		10.13	Street Walker	53.98	3.41						
		9.55	*Pole of*	59.54	12.50						
		3.29	*Catenary P.L. Xing*	66.74	3.09	0M^2					
		7.40	Trees	77.88	-0.43						
		5.86	Trees	84.43	8.88				+		
237-238	6.65	5.77	Ground	67.62	4.22		139.51				+
		15.86	Trees	3.23	-8.33						
		5.40	Trees	7.23	8.30				+		
		9.14	Tree	14.89	-5.04						
		3.58	Tree	25.15	2.14						+
		7.30	Tree	33.34	-2.57						
		3.51	Tree	36.57	5.04						+
		2.57	Tree	40.17	4.09						+
		4.58	Tree	46.03	6.20						+
		8.34	Trees	50.74	-4.06						
		5.82	Trees	53.70	-0.43				+		
		6.00	Trees	58.24	-0.78						
		4.38	Trees	60.48	3.81						+
		7.36	Trees	60.64	-3.10						
		6.60	Trees	61.29	-1.68						
		5.74	Trees	65.79	-1.11				+		
		2.62	Trees	66.62	5.24						+
		6.15	Trees	70.93	-1.15						
		3.62	Trees	71.51	3.09	1366M^2					+
		5.49	Trees	74.67	-0.60				+		
		3.63	Trees	84.31	4.82						+
		6.78	Trees	87.15	-1.89						
		4.21	Trees	87.24	2.19						+
		4.28	Trees	91.88	1.26						+
		7.98	Trees	94.32	-3.87						
		5.57	Trees	98.91	-0.79				+		
		9.08	Trees	98.92	-5.01						

the UK during the period April 2004–September 2004 on a number of different OHL routes.

During the period October–December 2004, the project team will re-convene to document the benefits, pros and cons of these vegetation management methodologies. If, as expected, the benefits are realized, it is the intent to roll-out this methodology to all vegetation maintenance work in the UK in 2005. It is expected that the NGT-US vegetation management program will also benefit from the lessons learned on the UK transmission system.

REFERENCES

Addison, Jacobs, Ray Richardson, and Merrett Rivkin. September 2003. Wide-scale Application of Lidar Data for Power Line Asset Management in National Grid Transco plc. CIGRE Committee SC22 Conference Proceedings.

Rhoads, Stennett et al. LIDAR ACCURACY – An Airborne 1 Perspective. 15/01/01. Airborne 1 Corporation, 300 North Sepulveda Boulevard, Suite 1060, El Segundo, CA 90245, USA.

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Scott Ryder has spent more than 32 years in the power transmission business at one of the Northeast's largest electric utilities. During that time, he was responsible for all phases of transmission project development and operation, including support of planning studies, project licensing, detailed line design, materials procurement, construction project management, facilities commissioning, O and M support, and real estate transaction coordination. Prior to joining EIG, Scott worked for the National Grid USA Companies, formerly the New England Electric System Companies. From 1986 to 1990, he served as Lead Project Engineer (Transmission) for the New England to Hydro Quebec HVDC Interconnection Project. In this role, he was responsible for the licensing, design and construction of 133 miles of 450 kV dc line, 52 miles of 345 kV ac lines and 36 miles of double-circuit 115 kV ac lines. Following this successful assignment, he was named Manager of Transmission Line Engineering, a role he maintained until joining EIG. In this position, he was responsible for a professional staff of eight and an annual capital budget exceeding $50M. Major accomplishments in this role included development of successful project licensing strategies, ensuring consistency of transmission designs and practices, ensuring licensing and environmental compliance on all transmission projects and successfully working to influence the regulatory climate relative to transmission siting issues. Scott holds a Bachelor of Science Degree in Civil Engineering from the University Of Massachusetts and a Master of Science Degree in Management Science and Engineering from Worcester Polytechnic Institute. He is a Registered Professional Engineer, Licensed Construction Supervisor, and member of the American Society of Civil Engineers.

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Brian Addison has been in the power transmission business for over 11 years, employed by National Grid Transco in the UK. He currently is Business Manager for Network Mapping Limited, an NGT subsidiary, responsible for the development and application of ALS technology with the NGT group of companies and marketing of these services worldwide. From 1983 to 2000, Brian worked in various roles within National Grid in the UK taking responsibility for the project management of power system telecontrol projects and the management of NGTs external bid process, for substation design and construction projects. Since joining Network Mapping in 2000, he has played a significant role in the development of NGTs ALS business and currently is responsible for the management of all business systems, including Business Planning, Bid Development, Resource Planning, Quality Assurance, Health and Safety and IT. Brian holds a Batchelor of Engineering Honors Degree in Electrical and Electronic Engineering from the University of Strathclyde, Glasgow, Scotland. He is a Chartered Electrical Engineer and a Member of the Institution of Electrical Engineers.

Visual Landscape Monitoring: A Tool for Characterizing and Managing Highway Corridor Landscapes

Gérald Domon, Philippe Poullaouec-Gonidec, and José Froment

In 1998, the Canadian Ministry of Transportation of Quebec initiated a pilot project using an alternative method to manage highway roadside vegetation. Reduced mowing has allowed natural regeneration to occur along the highway corridors. As part of a monitoring programme, the Chair in Landscape and Environmental Design at the University of Montreal was mandated to describe the effects on landscape generated by the new management method and to provide recommendations for its improvement. This paper presents the original methodological approach developed to address these issues. Key observation points were selected along the routes and diverse media (panoramic photographs, videotapes) were used to monitor changes in embankment vegetation (2000–2002) affecting the visual experience. These data were then used to assess the changing visual experience and the perception of users. "Expert" analysis and user survey revealed that ecological management contributed positively to landscape aesthetics, under certain conditions: management must take into account the highway's context and a diversity of experiences. Results also revealed the importance of informing users about the nature of the programme and the necessity to continue with some degree of maintenance in order to show that the resulting appearance is not a consequence of neglect. The research showed that to allow "everything to grow everywhere all the time" does not optimize the visual potential of embankment vegetation, and the necessity to develop a "landscape approach" for roadside management, supported by a monitoring system, which records the emergence and the disappearance of desired qualities. This is a promising field in which the Ministry of Transportation of Quebec will play an important role in the future.

Keywords: Landscape evaluation, characterization, management, highway landscape, highway corridor, ecological management, visual monitoring, monitoring, management of highway rights-of-way, user perception

INTRODUCTION

The Canadian Ministry of Transportation of Quebec (MTQ) began a pilot project in 1998 on the ecological management of highway corridors (Bédard et al., 2000; Bédard and Trottier, 1999). This study proposed to examine the effects of the modification in highway embankment management at the ecological, economic, safety and landscape levels, on three highway sections for a period of three years. The Chair in Landscape and Environmental Design of the University of Montreal was mandated to study the effect of management on the landscape characteristics of highway corridors. Because the change from intensive management to a so-called ecological[1] management allows the development of more diversified vegetation on the embankments, and therefore modifies its visual characteristics (Fig. 1), the project raises a set of questions about the landscapes traversed by the highway corridors. Are the visual characteristics of the embankments likely

1 Ecological management consists essentially of considerably reducing the mowing frequency, from a schedule of several mowing per year to a mowing schedule of once every three to five years.

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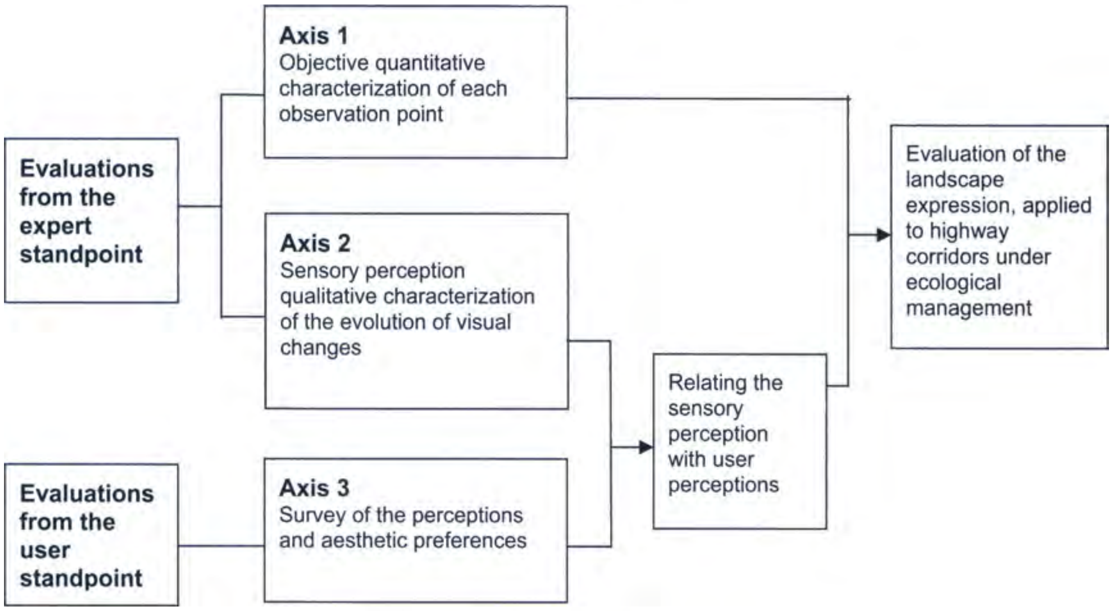

Fig. 1. Diagram of the methodological approach.

to contribute to the creation of new landscapes of interest or, on the contrary, simply hide those through which the highways are passing? How do users perceive these visual characteristics?

In order to address these questions a detailed knowledge of the visual characteristics arising from the new practices and of the perceptions of users was deemed necessary. Consideration was given to the relationship between the highway system and the area it traverses, to the contribution of embankments to the highway landscape, and to the tools best able to document the changes brought about to visual characteristics of embankments by the new type of management. The following pages present i) the conceptual approach and the research instruments developed for this project, ii) the results obtained, and iii) a discussion of the effect of these results on the future of the ecological management programme.

METHODS

Strategy and research instruments retained

Research on landscape evaluation over the last 30 years has led to the development of methods, which can generally be grouped into two broad categories (Daniel, 2001). On the one hand, there are "expert" methods, based on the premise that an expert is qualified to characterize and evaluate landscapes, based on recognized criteria. On the other hand, there are "user" methods, based on the perception that individuals have of the landscapes considered. The recent emergence of evaluation methods seeking to combine the expert viewpoint with that of the greater public, in order to evaluate landscape, is promising, but examples of real case studies remain relatively few (Daniel, 2001). The methodological approach chosen in this research project is derived from these so-called "combined" methods, which seek to provide factual knowledge of the evolution of the visual characteristics of the highway landscape, while *at the same time* provide information about its perception by users, in order to describe as precisely as possible the landscape experience produced (Fig. 1).

Based on the Visual Landscape Monitoring System (VLMS) (Domon and Poullaouec-Gonidec, 2003; Poullaouec-Gonidec and Domon 1999a; 1999b) developed at the Chair in Landscape and Environmental Design of the University of Montreal, the chosen methodological approach and research instruments rely on the retaking of photographic and video images, in order to systematically and precisely document the changes occurring in the landscapes in a context of ecological management of the embankments. This type of procedure, which consists in revisiting places which were photographed years, and even decades earlier in order to document, in a way, their "aging" (Nusser, 2001; Grison, 1998) and supply information for the purpose of land-use planning and management, forms the basis of the "visual monitoring" of highway corridors under ecological management.

The visual monitoring procedure consisted, first, of characterizing the visual dimensions of the highway corridors following the implementation of the ecological management programme. Secondly, the assembled information was analyzed using two complementary perspectives, that of the expert and that of the user. The "expert" evaluation sought to obtain a characterization that was as a complete as possible, by producing and analyzing data on the evolution of visual changes. The "user" evaluation sought to identify the perceptions and aesthetic preferences of the user, through the means of a semi-directed in depth survey of 31 respondents.

Approach and instrumentation

The initial approach chosen for studying the evolution of the visual characteristics of highway corridors was based on the selection of views and the systematic photographic retaking of these views. Because the number of views likely to be the object of visual monitoring is almost unlimited, however, in the context of highway corridors, a strategy for identifying the most significant views needed to be implemented. Following a thorough literature review, a map analysis of the three experimental corridors allowed us to identify a certain number of situations likely to highlight the embankments or the regional context, and a field inventory allowed us to make a final selection of 28 monitoring (observation) points. Photographic retakes were made of each observation point during the three years of the study, at a rate of 18 retakes per year. They were taken with consistent optical height, lens format and orientation angle. Six images, taken to cover a wide field of view (150–180 degrees), were assembled to create a single panoramic image (PhotoSuite 4.0 software). From an expert standpoint, these panoramic views formed the basic data for the quantitative and qualitative analyses (Poullaouec-Gonidec et al., 2000).

The panoramic images were initially supposed to form the essential data for the visual monitoring. A preliminary study of the images, however, rapidly revealed that the data analysis from the photographic retake of specific observation points, although representative, could not by itself account for the visual characteristics of a highway corridor which, by definition, is both linear and continuous, and that the perception of highway landscapes results from the collection of image fragments of different duration and angles. It was therefore decided to develop and combine different observation and characterization tools for evaluation purposes.

Because of the linear and continuous nature of highway corridors, the need to account for the visual characteristics of the totality of the corridors required the use of a novel method. Video retakes were thus made at regular intervals along the studied corridors, from moving vehicles, at various speeds and angles. Thanks to a successful collaboration with the Department of Vision and Geometric Modeling of the University of Montreal, these video retakes were analyzed with a moving landscape information system, in order to obtain images in the form of sequential strips. These images allowed for the instantaneous recording of the structure and characteristics of the planes of view and vegetation layers, as they appeared in lateral situations and in motion, as well as the variability of these visual characteristics through time.

From a user standpoint, selected panoramic views were presented to participants in paper format (colour reproductions) and in digital format, or QuickTime format. This software offered participants the possibility of doing visual sweeps of the image, of zooming in and zooming out, in a way that is similar to that of eye movements in a driving context. This visual tool was used in the interviews to help create a relationship similar to that of the movement of the gaze of users.

Finally, combining visualization tools allowed us to better approximate the real experience of the user, by using a set of still and moving images, treated in a way as to produce focusing and sweeping effects which serve to provide additional fragments of the real life experience of the user. In the absence of a computerized total simulation, recreating the experience accurately and entirely, the recourse to such a combination of multimedia tools appeared as the best way to reproduce as nearly as possible the experience perceived by the user. Multimedia presentations using combinations of characterization tools were used during interviews in order to present different aspects of the landscape representation to the participants.

Visual monitoring, expert standpoint

The analysis system used for characterization was based on the notion of aesthetic appreciation, and was applied along two different axes, the objective characterization (through quantitative analyses) and the sensory perception characterization (through qualitative analyses). The criteria of the quantitative analysis were mainly related to the measurement (importance, predominance, ubiquity, etc.) of certain aesthetic aspects, such as colours, shapes or textures. For the qualitative analyses, the objective was to determine how aesthetic dimensions (sensory or aesthetic perceptions) were affected, positively or negatively, by the new management method, while remaining conscious of the limits, among others, imposed by the multiplicity of individual appreciations (Souriau, 1990).

Derived from the work of Porteous (1996), the parameters chosen for qualitative analysis refer to significant traits and to features (Table 1). Traits are associated with the physiognomic aspects of a location (volume, shape, plane, colour, light, texture) and features are associated with distinctive particularities (rhythm, sequence, readability, complexity, archetype, emblem, identity). They form a whole called "characteristic traits," the particular effects of which contribute to the qualities of a location. According to their specific nature, the parameters were applied to photographic retakes or to videos.

The monitoring of the evolution of the landscape of rights-of-way consisted of two successive and complementary steps. The first consisted of a characterization aimed at evaluating the contribution of the embankments to overall right-of-way landscape expression. The second, the actual monitoring, had the objective of evaluating the evolution of this contribution. The

Table 1. Parameters chosen for qualitative analysis

a. Parameters related to trait

Traits	Retained attributes
Volume: aspect and appearance of an element, of an environment	*Aspect*: large, small, stout, massive, heavy, compact, filled, hollow, bumpy, etc. *Appearance*: undefined, faded-in, isolated, agglomerated, imposing, slender, linear, etc.
Shape: whole of the contours of an object, an element, resulting from the structure of its parts	Long, wide, high, low, full, geometric, cut-out, jagged, chiselled, etc.
Plane: horizontal or inclined surface representing the depths or distances in a visual frame	Abrupt, steep, oblique, parallel, superimposed, successive, limited, infinite, stratified
Colour: property of producing a particular visual impression, attributed to light, to objects or to matter (ref: Robert dictionary)	Mono- or polychromatic, warm or cool, dull, flat, satin or glossy, transparent, light, dark, contrasted, uniform, impressionistic, etc.
Light: state of natural lighting (daylight) producing visual effects	Brilliant, filtered, hazy, golden, pallid, opaque, twilight, backlighting, etc.
Texture: term referring to the appearance of matter (mineral and plant)	*Mineral texture*: polished, powdery, granular, soft, plastic, supple, rough, chalky *Plant texture*: spongy, soft, spiny, rough, delicate, cottony, velvety, satin-like

b. Parameters related to features

Features	Retained attributes
Rhythm: aesthetic feature of a general movement or distribution of elements through space at regular intervals	Sustained, measured, uneven, punctuated, harmonious, repetitive, etc.
Sequence: ordered feature of elements in an environment	Short, long, rhythmic
Complexity: feature that includes several different elements	Number, repetition and overlapping of components, reference or comprehensive elements
Readability: intelligible feature of an environment, which it is possible to understand	Total, partial, good or poor
Archetype: which has a model feature	Picturesque, natural, forested, pastoral, flowering prairie, etc.
Emblem: feature that represents a symbolic figure	Forest, rural, urban, heritage
Identity: feature of what is a significant (identifiable) location	Strong or weak character of the location, singularity

Table 2. Characterization of the overall right-of-way landscape expression

General characteristics	Traits and features of right-of-way landscape	Contribution of vegetation to landscape expression
	1. The significant traits: Volume, shape, plane, colour, light, texture	1. Aesthetic (and visual) effects produced
	2. The significant features: Rhythm, sequence, readability, complexity, archetype, emblem, identity	2. Predominance of the aesthetic expression 3. Aesthetic analysis

characterization was done for "time zero" of the monitoring, which corresponds to the first images taken on May 25 and 31, 2000[2] (Table 2).

The monitoring was done according to two gradients, the seasonal gradient and the annual gradient, in order to evaluate the variation in the contribution of embankment vegetation in relation to season and longer, year to year changes. Various analyses were done. The analysis of "vegetation singularities" sought to provide, as the name indicates, a general portrait of the evolution of the visual singularities of the embankment vegetation (colours, volumes, textures, and the aesthetic and visual effects produced), over the years of monitoring. For example, the reed-grass colonies located in the first plane of the agricultural plain landscape were analyzed using the chromatic scale, height, and volume, in order to evaluate the visual effects produced, and the evolution of these visual effects through time (Fig. 2). In other words, the analysis sought to evaluate if these effects remained stable, or were modified (altered or expanded) during a given year or through the years.

As for the analysis of "vegetation signatures," or the total portrait of the embankments and of their context

2 At that time of the year, the embankments have lost their winter coloration and the tree layer has generally taken on the aspect that it will conserve until fall.

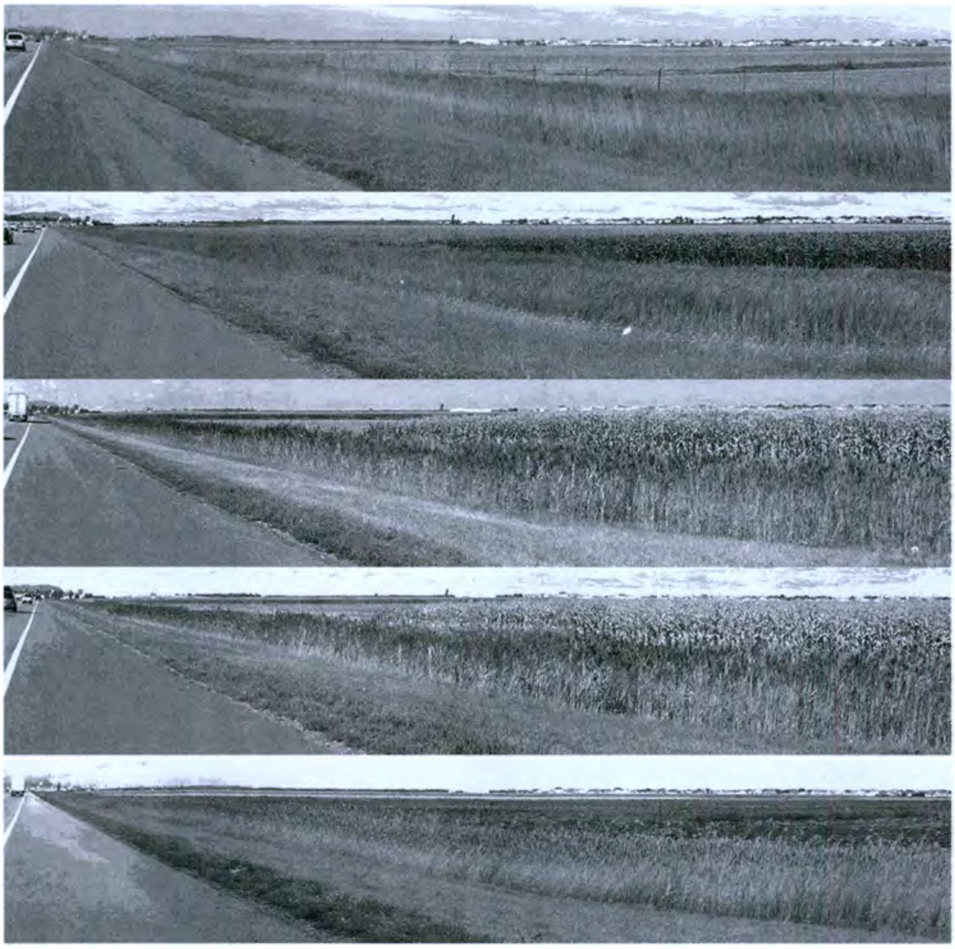

Fig. 2. Study of the "vegetation singularities" by comparative analysis of photographs along the seasonal gradient.

over all of the highway section, it sought to document the general evolution of the route, by comparisons between sequential strips along the seasonal gradient and the year to year gradient (2001 and 2002).

Monitoring, user standpoint

For the second part of this research, and based on the data collected with the tools presented previously, a qualitative approach was used, through an exploratory survey of users, in order to discover the range of perceptions produced by the new management regime, particularly from an aesthetic perspective. More specifically, the survey sought to determine: 1) the dominant dimension or dimensions of the appreciation (related to the ecological, aesthetic or functional dimensions); 2) the contribution of embankments to the appreciation of the highway route and to landscape quality; 3) the preferences regarding the aspect of the vegetation; 4) the general attitude towards the objectives of the management programme (ecological, aesthetic, economic, safety, etc.) which produces an appreciation, whether positive or negative.

Survey protocol, tools and user/respondent selection

The survey done on 31 respondents (non-representative sample, but diversified according to sex, age group, and occasional or frequent highway use) consisted of interviews of 1h15 to 1h30 in mean duration. Respondents were mainly recruited within the university network (publicity in the University of Montreal newspaper, on bulletin boards and on information monitors).

The participants were informed that they were participating in a study done on behalf of the Ministry of Transportation, the goal of which was to record user perceptions of highway landscapes. However, they did not know that they were evaluating an ecological management project, which allowed us to obtain their opinion on embankment vegetation. The objective was to find out if this vegetation is spontaneously noticed by the respondents, and whether or not it is an appreciated element, among the many that compose the highway landscape. In order to achieve this, respondents gave their appreciation of five panoramic photographs in digital format (QuickTime), showing different situations of embankment visibility, different contexts (wooded, peri-urban, rural) and diversified vegetation. Participants were then asked to answer questionnaires using colour reproductions. The classical tools, validated in several surveys on landscape perception, were used to obtain information about

Fig. 3a. In order to do this comparative analysis, the images were chosen because in spring, at this observation point, the central embankment takes on the appearance of a lawn, similar to what it would have looked like under intensive management. Highway 40, observation point 16, images taken on May 31 and August 29, 2001.

qualifiers/referents associated with the highway landscapes under embankment management (results of a list of 12 adjectives selected on a differential semantic scale), the attitude about the contribution of the vegetation to landscape quality (multiple choice questions) and the preferences of users between one or the other option (aspect presented under intensive or ecological management), and the effects of contexts and seasons, by comparisons of pairs (Fig. 3a) and series of images showing the embankments during three seasons (Fig. 3b).

The last part consisted of open questions, following the information presentation on the ecological management programme. An explanatory brochure about the programme was handed to the participants and a slide presentation (PowerPoint software) was given, showing images (photographs and videos) presenting the visual effects of the ecological vegetation management programme. After receiving this information, respondents were questioned on their general attitude (agree or disagree) towards this programme, and the main motive underlying their attitude (ecological, aesthetic, economic, etc.). They were finally invited to give their opinion on the development of the programme (i.e.: extension to general use) and on certain management aspects (suggested improvements).

The data collected from the users were submitted to a thematic analysis (Paillé, 1996), and the results were confronted with those of the expert analyses in order to improve the final recommendations.

RESULTS AND DISCUSSION

Considerations about the consequences of the results on the future of the ecological management programme

The overall duration of the project is limited in view of the fact that many phenomena associated with ecological succession occur on a time scale that largely exceeds three years. Under these circumstances, only a continuation of monitoring over the middle term and the long term will allow for clear answers to some of the questions raised by the ecological management of highway embankments. It is possible, however, to propose certain elements, referred to as "founded hypotheses," which could allow us to initiate some reflection on the future of this novel programme. These elements are presented from two perspectives, that of the expert and that of the user.

Expert perspective

The expert analysis reveals that the phenomena generated by the ecological management of embankments are expressed according to different time periods. On a short time scale (within a year), the most striking visual effect is the richness of the vegetation induced by the new management method. To the nearly uniformly green ribbon usually characteristic of highway embankments, ecological management has substituted embankments that are characterized by chromatic patterns, volumes and textures that vary considerably spatially and temporally, with a few exceptions.

On a longer time scale (in the order of several years), the reduction or abandonment of mowing along highway corridors is likely to generate, at the same location, a considerable diversity of situations in visual terms. Over a period of one or several decades, however, it is anticipated that two phenomena will occur: a certain increasing uniformity of the vegetation, and the masking of significant elements of the highway landscape (Fig. 4). The data collected, however, lead us to think that vegetation succession occurs at a much slower rate on highway embankments than on abandoned agricultural lands. It is therefore important to define long term visual monitoring strategies to document this evolution.

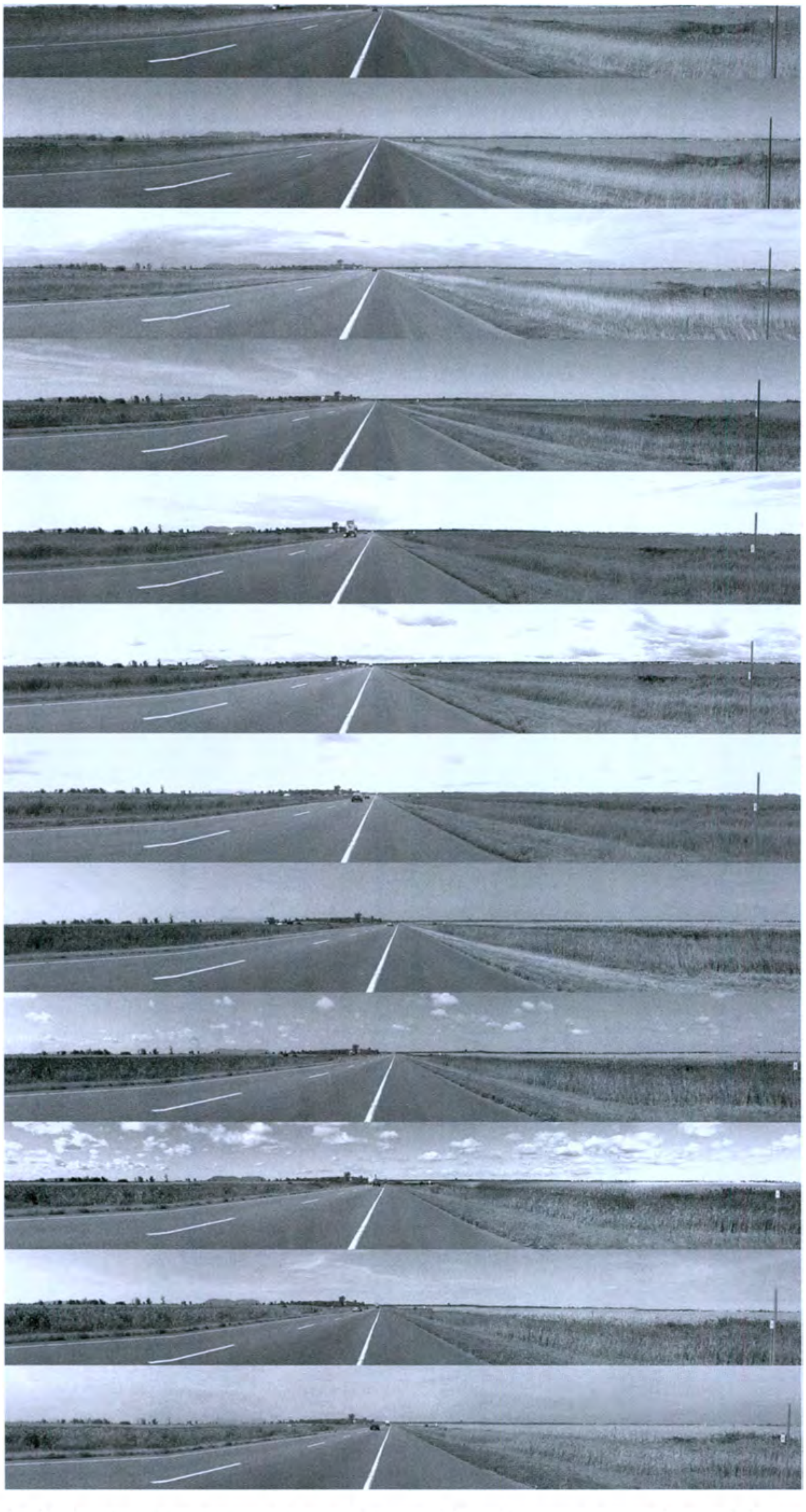

Fig. 3b. Seasonal poster presenting a series of images of the embankments between May and October.

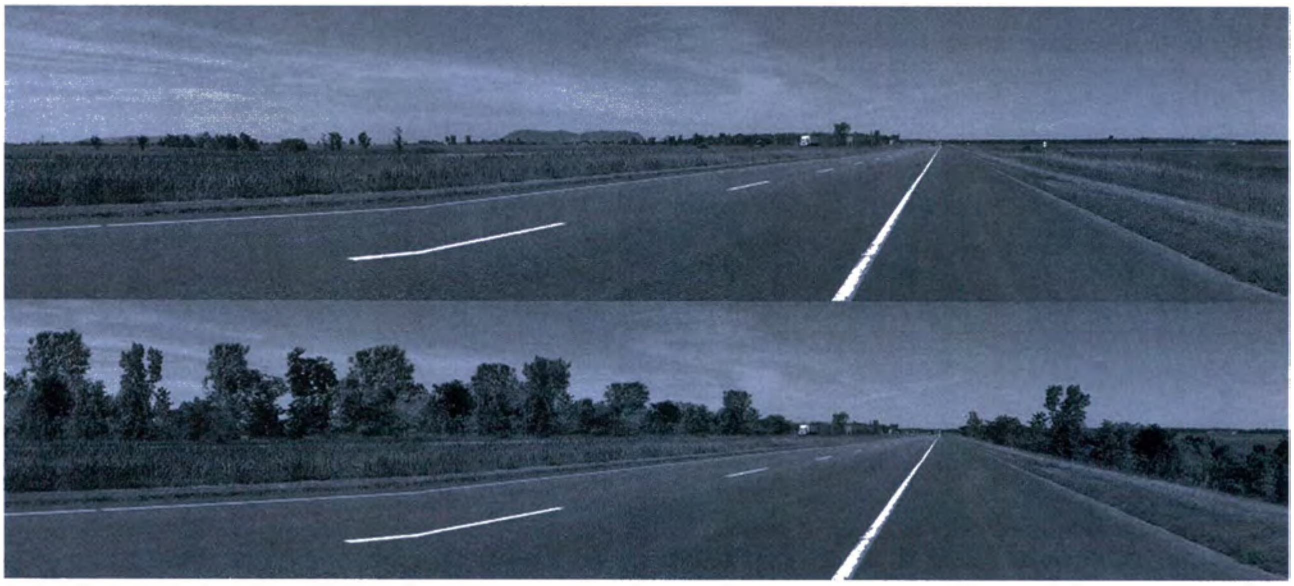

Fig. 4. Top photograph. Highway 20 towards Montreal, with view of Mount St-Hilaire, a strong identity element. Bottom photograph. Visual simulation of the same location. Over the long term, the woody vegetation on the shores may mask or at least filter the strong identity elements.

Fig. 5. The visual attraction located in the third plane (a mountain in this case) is visually "brought closer" to the user because the embankment vegetation masks the elements located in the second plane (Highway 20 towards Montreal, observation point 3, September 2001).

This having been said, the monitoring analysis allows us to explore some avenues for the future of the ecological management programme. Some of these are of a more general nature; others are more specific and related to particular situations and contexts. Thus, at a general level, it is important to note that the application of the principles used in this programme can generate opportunities. First, the results show that the ecological management policy contributes to requalifying the highway infrastructure by decreasing the overwhelming presence of the road in the highway landscape. Furthermore, the vegetation within the right-of-way can generate or accentuate the impression of "nature." The disappearance of the wide, uniformly mowed band between the pavement and the ditch brings the user closer to nature, increasing the feeling of being in nature. Finally, the right-of-way can become a tool for the improvement of the context. For example, as confirmed by user comments, in an open plain situation, the right-of-way becomes one of the elements of the composition of a landscape scenery revealed over several kilometres: it contributes to the beauty of the environment.

Although the data analysis from the expert standpoint reveals that the appreciation of the embankments is most often inseparable from the characteristics of the context, we should note that the contexts of visual openness and closure of the highway infrastructure confer particular roles to rights-of-way. In a visual openness situation, they directly participate in the readability of the area, and improve spatial orientation and filtering, or, in other words, they contribute to the "visual blurring" of the second visual plane. Also, at the same time, they indirectly contribute to highway safety. Furthermore, this visual blurring of the second plane confirms the "scenic" role of embankments, because the visual attractions located in the third visual plane (for example, a mountain, a church steeple, a woodlot, etc.) are visually "brought closer" to the user (Fig. 5).

In closed-in visual situations along highways, most often associated with wooded areas, the corridor effect caused by the lateral framing by adjacent forests creates, for most of the year, monochromatic masses that can become monotonous over long distances. Within an "extensive design" perspective using "natural vegetation," we could at times seek to make the right-of-way as distinct as possible and separate it visually from the darker depths of the woodlot or the forest, whereas at other times we could try to blend it as much as possible with adjacent woods in order to reinforce the image of "nature," by the use of indigenous shrubs and perennials.

Finally, rights-of-way generate an "alignment," or a series of parallel lines (made up of pavement, shoulder, embankment vegetation and sometimes a talus or a fence) converging towards a visual end point. In the case of rights-of-way with ecological management, however, this alignment is polychromatic and varies considerably according to the season (spring, summer and fall), which creates new management potentials.

In addition to these general findings, the rhythm produced by openings and closures of the immediate context, in relation to the visual effects created by the vegetation of the embankments under ecological management, produces a set of additional potentialities for the application of the new principles of right-of-way management. For example, it could imply improving significant elements of the landscape (3rd or 2nd visual planes), using the verticality and the density of certain plants in the central embankments in order to create visual screens to reduce the presence of opposite highway lanes.

The results, however, also show that "letting everything grow everywhere all the time" does not suffice to optimize the visual potential of the vegetation, and that we must avoid substituting a uniform management method (the "all lawn") by another equally uniform method (the "let all grow"). Instead, we should opt for sometimes letting nature go, and sometimes for lending it a helping hand in order to achieve the expected objectives. In other words, we must recognize the importance of the scenery aspect in the highway corridor management policy, and to base this policy on a simple visual monitoring procedure able to record the evolution of the characteristics of the embankments and of the larger context, and of the landscape resulting from their interaction. On this issue, the results of the expert perspective coincide with those from the user survey, in that they support the importance of an "extensive design with the natural vegetation."

The setting for future intervention would therefore include highway corridors as an environment belonging to a transportation concern, but the landscape characteristics of which are inseparable from the territory being traversed. Consequently, several additional research directions can be put forward in order to increase our understanding of highway routes, of the territories they traverse, of plants and of climatic specificity. In the case of plants, for example, it is important to improve our knowledge of the visual and sensory qualities of native species (i.e. type and variability in the colour of stems, leaves, flowers, texture), and also to improve our knowledge of the ecological characteristics of these species, particularly with respect to their capacity to maintain themselves in highway environments and their response to selective mowing practices.

The ecological embankment management project opens up two new and complementary practices, that of developing real "highway landscape projects" and of the "extensive design with natural vegetation."

User perspective

Often corresponding to the findings of the analyses from the expert perspective, the information collected from the user survey provides several new avenues with respect to the future of the ecological embankment management. Certain considerations, however, must be clearly stated before these avenues are discussed.

First of all, although the analysis was mainly focused on the perception of the embankment vegetation, the results have shown that multiple other factors contributed to make the highway landscape experience a pleasant one. Thus, for example, the quality of the pavement of the road aroused a great deal of spontaneous comments, and many respondents were interested in the qualities of highway routes (presence of curves, climbs and descents) which in their opinion added to the landscape experience.

Furthermore, the results suggest that management must be considered in relation to total routes. Even when certain views were presented to users through images, these images were put into "context" within routes. For example, the visual qualities of reed-grass colonies are appreciated, but users will quickly add that these can become boring over too long a distance. In this sense, vegetation management must seek to produce a diversity of experiences and situations.

The results also show the importance of an adequate understanding of the objectives of the management programme. We should recall that most users, whether or not they appreciated the changes brought about in the embankment vegetation, said that they agreed with this type of management.

Finally, coinciding on this point with the expert analyses, the survey reveals that the surrounding context and the perception of various elements outside of the highway right-of-way exert an influence on the perception of the embankment vegetation by users. This implies that the question of the embankment vegetation cannot be addressed by setting aside the context within which the highway is located. Overall, three situations are observed. First, there are sometimes too many elements that mar landscape quality

Fig. 6. The results show that when too many elements reduce the quality of the landscape, the visual effects generated by the embankment vegetation are not sufficient to counteract these annoyances (Highway 40, observation point 12, images taken in September 2001).

for the visual effects generated by the embankment vegetation to be considered sufficient to counteract these annoyances (Fig. 6).

Conversely, there are sometimes certain elements of the context that are so attractive and valued, that the embankment vegetation is ignored. Finally, there are situations where the combination of the context and the vegetation of the embankment produce full satisfaction for the users. The question of the appreciation of highway embankment vegetation must therefore be addressed in a more general context.

The results also reveal that the vegetation produced by the ecological management programme can contribute to the creation of "pleasant" and "high quality" landscapes. Indeed, two landscapes located in an area that did not present a great interest, at least at first glance, garnered the highest ratings from respondents. Similarly, in the case of landscapes closed-in by woods, in the absence of elements that could particularly attract attention, the vegetation of the embankments seems to be generally noticed and appreciated. In such a context, it would be appropriate to build on this favourable visual perception in order to create varied vegetation combinations, and eventually proceed to develop regional "emblematic attributes" using typical plant species. On the opposite, in landscapes well provided with contextual elements of interest, the survey reveals that the user's glance has fewer chances of falling upon the embankment vegetation. In such contexts, it is not likely pertinent, or at least a priority, to seek to improve the visual quality of embankment vegetation.

If some situations can provide for the emergence of rules that are both simple and few, others will require more in depth study. Such is the case for landscapes that, in spite of a pleasant setting at first glance (i.e. rural setting), present a high number of jarring elements (hydroelectric pylons, billboards, power line crossings, and businesses). In these cases, some might argue that the irregular, even "jarring" appearance of the vegetation originating from ecological management adds to the ill-matched nature of the landscape and may even decrease its appreciation.

Finally, matching those of the expert analysis, the results on the seasonal preferences suggest that early spring and late fall may be critical periods because of the impression of neglect that can be created by an overabundance of "dead weeds," as well as the dull appearance of the embankments.

CONCLUSIONS

The "visual monitoring" project has provided the opportunity to develop new tools for characterizing landscapes and to generate certain findings that are significant for the future.

With respect to the development of research instruments, considerable effort was allocated to provide a better assessment of the experience of users, which seems essential for evaluating the performance of the landscape expression of highway corridors under ecological management. Furthermore, although the limitations of panoramic views taken at specific locations were rapidly understood, they were nevertheless very useful in documenting the vegetation particularities of the embankments. Experience also confirmed the merits of using tools that are able to simulate movement along a route, as well as capable of documenting the evolution of landscape expression of the totality of a highway section, and not only from specific observation points. This instrumentation, which could be labelled a veritable characterization "tool box," can be useful on a larger scale, for an eventual observatory of the landscapes of the green holdings managed by the Ministry of Transportation of Quebec, as well as in other contexts.

With respect to the results obtained, it is important to mention again that the visual monitoring done over three years shows without a doubt that the current ecological management policy for highway embankments contributes to the "re-qualification of the highway infrastructure," as well as contribute in a significant way to landscape considered to be "pleasant" and of "high quality" by users. The survey reveals that two conditions are essential for the appreciation of the new

Fig. 7. The systematic and strict mowing of the green shoulder sends a message to the user that the appearance of the embankments under ecological management is not simply the result of abandoning maintenance, but instead of a change to another management method.

management method by users: an adequate comprehension of the objectives of the programme, and a systematic and strict mowing of the green shoulder. This mowing will remind users that the new characteristics of rights-of-way are not the result of simply abandoning their maintenance (Fig. 7).

The research also clearly shows that an approach consisting of "letting everything grow everywhere all the time" would not allow the achievement of an optimal visual potential for the vegetation induced by the new management method. The expert evaluations, as well as the user survey revealed the necessity of developing this new field that we have labelled, on a temporary basis, as "extensive design with native vegetation." This new field should be based on intervention principles likely to maximize the potentials offered by the new management method, while taking into account the characteristics of both the rights-of-way and of the wider context.

Finally, the landscape management of rights-of-way should be based on a sentinel system capable of rapidly detecting the disappearance as well as the emergence of desired qualities, and consisting of i) the systematic monitoring of the entire highway route, ii) the monitoring at regular intervals of the most significant locations of the route, and iii) the monitoring of the most significant vegetation groups in terms of visual impact and distinctiveness.

Far from closing the debate on the "ecological management of highway rights-of-way," this study provides the foundations of a new and very promising field, with a high potential for international visibility, which we could in effect designate as highway landscape management, a field in which the Ministry of Transportation of Quebec can play a major role in years to come.

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REFERENCES

Bédard, Y. and D. Trottier. 1999. La gestion de la végétation des corridors autoroutiers : la nouvelle approche québécoise. Colloque Corridors de déplacement des personnes et des ressources. Quatorzièmes entretiens du Centre Jacques-Cartier. Décembre 2001. Lyon.

Bédard, Y., D. Trottier, L. Bélanger, et al. 2000. Managing the green heritage of Québec's highways "A new ecological approach." Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Sept 9–13, 2000, Calgary, Canada. 147–154.

Daniel, T.C. 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. Landscape Urban Planning, 54: 267–281.

Domon, G. and P. Poullaouec-Gonidec. 2003. L'intégration du temps à la gestion et à la mise en valeur des paysages. In: Poullaouec-Gonidec, p., Paquette, S., Domon, G. (Eds.) Les temps du paysage: actes du colloque tenu à Montréal, les 23 et 24 septembre 1999. Montréal, Presses de l'Université de Montréal, 143–169.

Grison, L. 1998. Le "vieillissement des lieux". Photographier, décrire-écrire. L'espace géographique, 3: 276–279.

Nusser, M. 2001. Understanding cultural landscape transformation: a re-photographic survey in Chitral, eastern Hindukush, Pakistan. Landscape and Urban Planning, vol. 57, pp. 241–255.

Paillé, P. 1996. De l'analyse qualitative en général et de l'analyse thématique en particulier. Revue de l'Association pour la recherche qualitative, 15: 179–194.

Porteous, J.D. 1996. Environmental aesthetics: ideas, politics and planning. Routledge, London; New York. 290 p.

Poullaouec-Gonidec, P. and G. Domon. 1999a. SMVP—Système de monitoring visuel des paysages québécois. Cédérom Chaire en Paysage et environnement, Université de Montréal.

Poullaouec-Gonidec, P. and G. Domon, 1999b. Nature et contribution du suivi de l'évolution des paysages: le cas du SMVP (Système de monitoring visuel des paysages). Prévoir l'avenir: les évaluations d'impacts pour un nouveau siècle. Les actes du 4ème Colloque international des spécialistes francophones en évaluation d'impacts. Secrétariat francophone de l'Association internationale pour l'évaluation d'impacts. Univ. of Strathclyde, Glasgow, Scotland, 213–234.

Poullaouec-Gonidec, P., G. Domon, S. Paquette, and C. Montpetit. 2000. Roadside Vegetation Management on Québec's Highways: A Visual Landscape Monitoring Research Project. Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Sept 9–13, 2000, Calgary, Canada. 155–163.

Souriau, É. 1990. Vocabulaire d'esthétique. Éditions PUF, Paris.

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Modifications in Viewer Appreciation of Highway Landscape Following the Implementation of Ecological Management in Quebec, Canada

José Froment and Gérald Domon

The Canadian Province of Quebec's Ministry of Transport has modified management practices on highway corridors. This initiative, called ecological management, consists of a considerable reduction in the frequency of mowing on the embankments, which radically changes their appearance. The impact of ecological management on biodiversity has been well documented. Its effect on the aesthetic appreciation of the highway landscape is far less understood. In order to improve our understanding of the effect of ecological management on viewer appreciation, a case study was carried out on the Laurentian Autoroute in Quebec, Canada (A-15 North). A landscape characterization was compared with the results of photographic inventories taken by 38 regular users equipped with disposable cameras. The results showed that the vegetation on the embankments seems to rarely contribute to overall appreciation of the landscape or even grab the attention of users. The results, however, did demonstrate that users appreciate the aesthetic qualities of natural elements, and their proximity to a natural setting. Ecological management can thus be used to establish a connection between the natural setting and the user. Ecological management of embankments could play an important role in a qualitative improvement of natural heritage and its associated aesthetic appreciation, provided that embankment management is done in association with the management of the surrounding landscape.

Keywords: Highway corridor, roadway corridor, landscape, ecological management, intensive management, user appreciation, ROW

INTRODUCTION

The Province of Quebec's Ministry of Transport recently undertook a transition toward an ecological management of roadway corridors. Essentially, this management consists of substantial reduction in the frequency of mowing on road embankments in order to naturalize them. On the landscape plan, the objectives of the Ministry of Transport are to increase landscape diversity, harmonize visual characteristics of roadway corridors with their context and improve the general landscape quality of roadways (Bédard et al., 2000; Bédard and Trottier, 1999). These objectives suggest that roadside vegetation could contribute to an improvement in the aesthetic quality of highway landscapes; which largely remains to investigate.

A study was conducted on a highway section (Fig. 1) where intensive management practices could be compared to ecological management practices, on two successive lengths of the highway corridor (the twenty-one kilometres in the South of the study area are managed intensively; the thirty-one in the North are managed ecologically). During summer 2001, a systematic inventory of the visual characteristics of the landscapes and the embankments was completed. During the same period of time, disposable cameras were distributed to regular users, who were asked to photograph their favourite views. The images taken by participants were compared with the results of the systematic inventory, to determine if the ecological management of embankment vegetation improves user appreciation of the landscape.

The following pages will present the methods and the results of this study. These results will be discussed

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

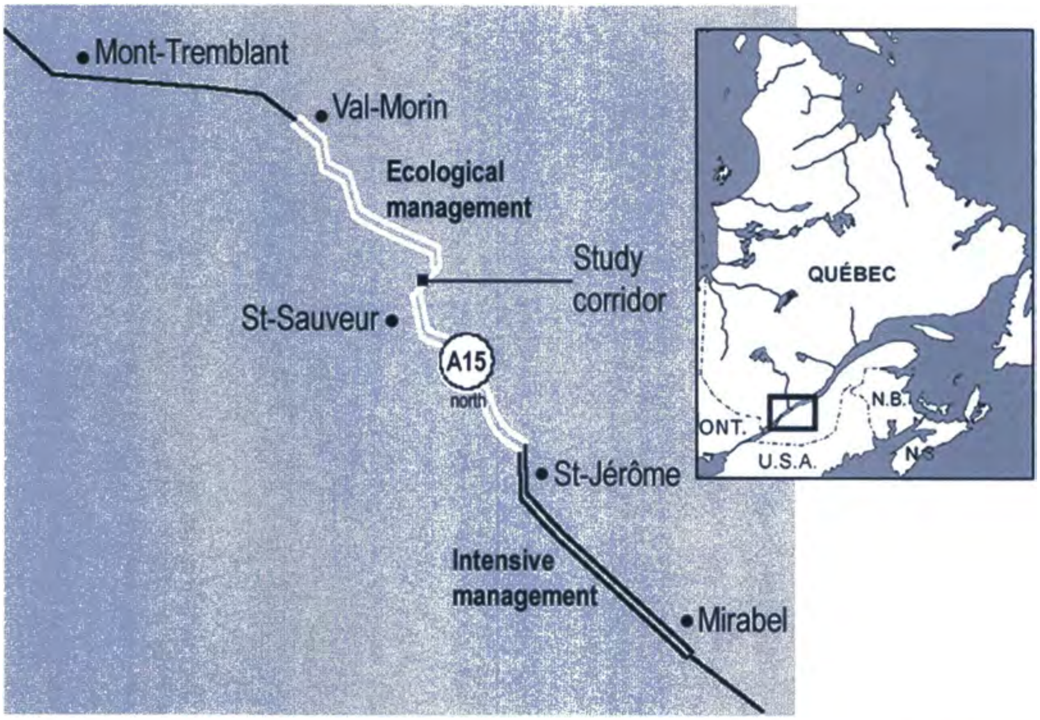

Fig. 1. The study area is a highway corridor passing through two large physiographic units, the Saint-Lawrence Lowlands in the South and the Canadian Shield in the North. Along the highway corridor, two embankment management methods are sequentially applied: 21 km in the South are managed intensively and 31 km in the North are managed ecologically.

with respect to: i) appreciation of highway landscapes, ii) the contribution of embankments and their vegetation to viewer appreciation, and iii) the future of ecological management of roadways. Courses or actions are suggested to contribute to the improvement of the landscape experience of highway landscapes.

METHODS

Methodologic strategy

For practical reasons, and because of the difficulty of accessing landscape representation through verbal descriptions (Luginbuhl, quoted in Michelin, 1998), surveys dealing with landscape appreciation often use representatively selected photographs. The use of photographs is widely considered to be a valid method of landscape representation (Daniel and Meitner, 2001). However, there is a possible bias to be found in the difficulty of evaluating the degree to which a photographed selection is representative due to the quality of the image obtained and the landscape represented. It was decided to employ personal photographic inventories taken with a disposable camera. Often referred to as Visitor employed photography or VEP (Chenoweth, 1984), this method allows the researcher to obtain the specific landscapes valued by users, thus avoiding the possible bias brought by pre-selected images (Dakin, 2003; Yamashita, 2002; Lelli, 2000; Michelin, 1998; Taylor et al., 1995; Chenoweth, 1984).

Most studies that have used the VEP method have done so in association with a process of photo-elicitation, either by using a booklet in which participants record the location and the subject of the pictures, and why they were taken (Taylor et al., 1995; Cherem and Driver, 1983), or by an interview with the participants to capture meanings and associations ascribed to the landscapes (Dakin, 2003; Stewart et al., 2004; Michelin, 2002; Lelli, 2000).

In this study, the process was adapted to the evaluation of highway landscapes, given the difficulty for participants to stop to record written information. The process was therefore done in two steps, by a photographic inventory followed by a questionnaire mailed to the participants. This adapted method makes it possible to obtain two types of information. The data from the photographic inventory supplied a general picture of the appreciation of the highway landscape (what was appreciated and at what frequency). The data from the follow-up questionnaire provided further information on the general appreciation of embankment vegetation.

The approach was as follows: a general description of the route and an exhaustive inventory of flowering areas on embankments likely to be noticed by participants, were carried out during summer 2001. At the same time, a disposable camera was given to participants with an instruction sheet and a return envelope. After participants returned the disposable cameras and the films were developed, a personalized questionnaire was sent to all participants.

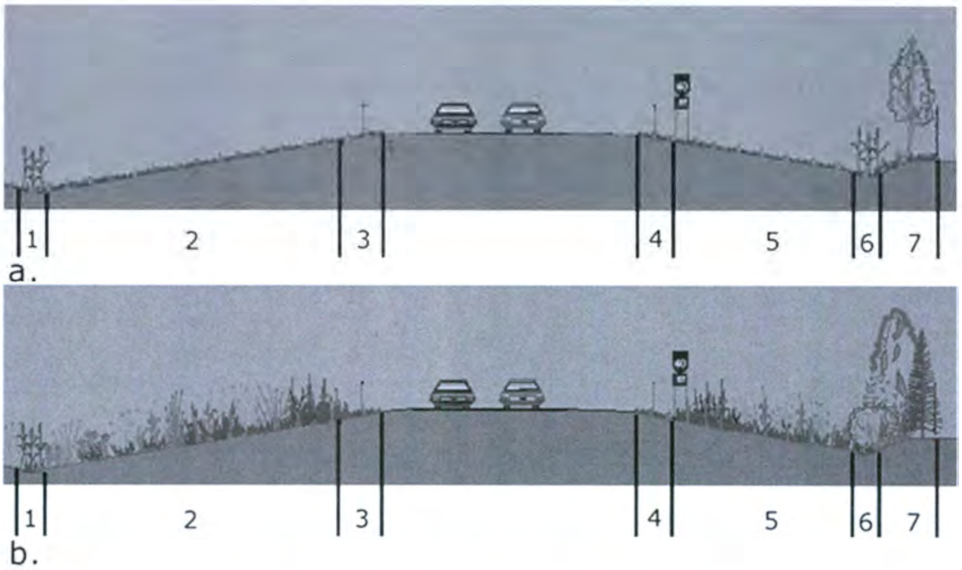

Fig. 2. Section view of the different parts of highway embankments under the two management methods. From left to right: 1. Central ditch; 2. Interior talus; 3 and 4. Green shoulders; 5. Exterior talus; 6. Exterior ditch; 7. Outer bank. Under intensive management (a), the green shoulders and the taluses are regularly mown, the ditches are periodically cleaned and the outer banks remain largely untouched. Under ecological management (b), the green shoulders (3 and 4) are mown periodically and all other sections of the embankment are subject to a significant decrease in the frequency of mowing. Source: Bédard and Trottier, 1999.

The study area

The studied route (the A-15 North highway between Mirabel and Val-Morin) is characterized by visual diversity due to its changing configuration and topographic variation. The corridor passes through two large physiographic units: the Saint-Lawrence Lowlands in the South and the Canadian Shield in the North. The lowlands are characterized by varied land use (agricultural, industrial, and residential) interspersed with small woodlots, which are supplemented by vast rural areas in the north. The sector situated on the Canadian Shield is characterized by steep hills (closely undulating hills), dominated by northern temperate forest. A detailed description was done for both the northbound lanes or "northbound route" and the southbound lanes or "southbound route." The descriptions were made by segmenting the route into 13 landscape units.[1] The landscape units were plotted and charted.

The sequential ordering of the two vegetation management methods of the highway embankments provided an opportunity to explore their respective influence on user appreciation. Highway embankments in Quebec are made up of sections running parallel to the roadway on both sides of the road (Fig. 2). Normally, there is a strong stratification of vegetation due to the moisture gradient from the road up to the outer bank, favouring plants with different soil requirements (Fischesser and Dupuis-Tate, 1996). The bottoms of ditches are characterized by wetland plants such as cattail (*Typha angustifolia*), purple loosestrife (*Lythrum salicaria*) or reed-grass (*Phragmites communis*). Left untouched, vegetation on the outer bank generally is composed of woody species grouped in thickets and interspersed with herbaceous plants in colonies, such as goldenrod (*Solidago canadensis*) and fireweed (*Epilobium angustifolium*), which are further along in plant succession than are grasses (Gérin-Lajoie and Lévesque, 2002).

Traditionally, maintenance is done regularly according to an established pattern: the green shoulders and the taluses are mown several times per year and take on the appearance of lawns (Fig. 2a). Under ecological management, taluses are mowed only every three to five years, allowing the establishment of species representative of dry prairies (Fig. 2b). At the beginning of summer, the taluses take on the appearance of a green prairie, made up mainly of sedges and grasses interspersed with annuals and perennials in bloom, which make a colourful mosaic.[2] As summer progresses, colours gradually fade in intensity and decrease in number in the maturing herbaceous layer.

Inventory of plants in flower

A systematic inventory of herbaceous plants in bloom on the central and lateral embankments was taken at the end of June 2001. This was done in order to obtain a general portrait of plants located on the embankments that could possibly retain the attention of viewers. The

1 It should be noted that the borders of the landscape units vary slightly according to whether the route is northbound or southbound. (Adapted from the Ministry of Transportation, Quebec, 2001.)

2 Plant mosaic is defined as a grouping of plants made up of separate, varied and colourful individuals whose juxtaposition gives the impression of being a mosaic.

inventory was carried out by a team of two investigators riding along at 10 km/h on the shoulder of the highway, in both directions. An empirical method was used: only the colonies presenting sufficient contrast with their immediate context (dominated by shades of greens) were characterized, given the assumption that they were likely to retain the attention of viewers at high speeds (Jackle, 1987). Also, a minimum threshold of 3 square meters for a plant mass of homogenous colour and 10 square meters for a flowering mosaic were assumed, empirically, to be able to capture the attention of viewers. Between June and mid-August 2001, a total of 111 plant colonies were identified and characterized in the inventory, which constitutes an exhaustive portrait of the embankment on the two routes.

User survey

The user survey had two phases: a photographic inventory and a related questionnaire, which were carried out in July and September 2001 respectively. Thirty-eight regular users of the corridor (20 men and 18 women) were recruited from the workers or clientele of local businesses (clients and employees of golf courses, employees of a local landscape nursery and municipalities). The sample was not representative; however it was balanced according to age and sex. The sample was equally divided (19–19) between the residents of the metropolitan region of Montreal and residents of the Laurentians (between St-Sauveur and Mont-Tremblant). The conditions for appreciation are modified through the prior knowledge of the route, and, over time, a user builds personal cognitive structures of a route, which are characterized by a series of determinant and structuring elements (Houlet, 1993). Regular users were chosen to obtain the most valued landscapes based upon established experience of the routes and the elements which provoked an immediate appreciation such as, flowers on embankments. Also, a good previous knowledge of the route could contribute to providing respondents with a certain facility in taking photographs while driving.

The participants received a disposable camera and an explanatory brochure. In order to avoid having participants focus their attention on the negative aspects of the landscape, which seem to provoke the greatest reactions (Michelin, 1998), the instructions for photographic inventory were oriented towards the appreciated elements (positively perceived). The instructions were presented in these words:

> *"All that you need to do is to photograph the landscapes or the elements which seem to you to be the most enjoyable along the route, and to return the camera to us. The photographs will allow us to answer these two questions: According to you, what are the most beautiful landscapes of the route? According to you, what are the elements of the landscape which add to its attractiveness?"*

This formulation sought to diversify the images taken, and to avoid a possible problem related to the use of a camera, which is the desire to take "good" pictures.

The participants received a disposable camera during the first week of July 2001. They took pictures between the 6th of July and the 12th of August. After the elimination of photographs taken outside of the study area, a total of 818 photographs were retained. The physical location of the scenes depicted in the photographs was identified and pinpointed on maps. In order to facilitate analysis, the images were grouped in eight categories corresponding to their dominant component (Fig. 3). These categories are: road images (Fig. 3a), mountain(s) (3b), village (3c), rural space (3d), suburban space (3e), tourist site (3f), natural space (3g), and embankment (3h).

The next step of the study consisted in a personalized questionnaire with three objectives, as follows:

1. to obtain specific information on the intended subject of the images;
2. to obtain comments; and
3. to evaluate the impact of ecological management on the overall appreciation of the landscape.

The questionnaire was mailed to participants in September 2001. For each participant, the questionnaire consisted of colour prints of all of the pictures, in which embankments were visible, that the participant had taken. Space was provided for comments beside each picture. Participants were asked to circle the elements they sought to photograph, and to add comments if they wished. The information on the intended subject of images was to avoid a problem associated with the use of disposable cameras, since these cameras do not allow the photographer to zoom in on specific details. A response level of 71% (27/38 people) was obtained for the questionnaire.

This method allowed us to make a double examination of the information obtained. First, all of the photos were analysed in order to compile the frequency of the most photographed views, image types and their distribution along the routes. Secondly, the distribution of the photos was analysed using the additional information provided by the questionnaire, in order to evaluate the contribution of embankments to landscape appreciation and to determine in which proportion and in which conditions this contribution was noticed by the participants. The use of a double examination allowed us to validate the results obtained through the pictures of the photographic inventory by comparing them with the details obtained through the additional questionnaire.

RESULTS

Number of images taken

The number of images taken on the two routes was 818, or a general average of 21.5 images for the 38

Fig. 3. Classification of the images taken by participants.

participants, distributed as follows: 399 (48.8%) for the northbound route and 419 (51.2%) for the southbound route. The answers obtained in the questionnaire about the frequency of use of the route allowed us to determine that for the 27 respondents, 16 were regular users of the route (at least once a week) and 11 were occasional users (once a month or seasonal use). The regular users took an average of 20.3 photos; the occasional users took an average of 21 photos. The respondents living in the metropolitan area took an average of 20.7 photos, and the respondents living in the Laurentians took an average of 22.3 photos.

Types and location of inventory images

Images of the mountains (33.1% northbound and 27.9% southbound) and of the routes, aligned with the highway direction, or axis (30.9% and 37.5%), were the most numerous, followed by rural scenes (19.7% and 15.6%). Images of natural scenes accounted for approximately 10% of the images, and those of tourist sites, villages, and embankments were few in number (Table 1).

The images of the roadway were photographed by a high percentage of participants on both routes: 85.7% (30/35 participants) for the northbound route and 94.6% (35/38 participants) for the southbound route. Likewise, images of mountains were photographed by the vast majority of participants (85.7% or 30/35 and 91.9% or 34/38). Nature scenes were photographed by approximately half of the participants. Very few participants photographed a village (St-Sauveur); only 7/35 participants on the northbound route and just 1/38 on the southbound route. The images of a suburban environment were taken by approximately a third of participants on either route (Table 2).

A detailed examination of the images revealed several views which were photographed by more than

Table 1. Distribution (%) of total images taken by participants

Route	%	Type of image							
		Road	Village	Rural space	Mountains	Tourist site	Suburban space	Natural space	Embankments
		%	%	%	%	%	%	%	%
Route 1	48.8	30.8	1.4	19.7	33.1	1.3	2.5	9.2	2.0
Route 2	51.2	37.5	0.4	15.6	27.9	3.7	1.5	10.2	3.2

Table 2. Proportion (%) of respondents according to each type of image

Type of image	Number of respondents	Number of respondents
	Route 1	Route 2
Mountain(s)	85.7% (30/35)	91.9% (34/38)
Road	85.7% (30/35)	94.6% (35/38)
Rural space	68.6% (24/35)	62.2% (23/38)
Natural space	42.9% (15/35)	56.8% (21/38)
Suburban space	34.3% (12/35)	18.9% (7/38)
Villages	20% (7/35)	2.7% (1/38)
Embankments	20% (7/35)	18.9% (7/38)
Tourist site	11.4% (4/35)	35.1% (13/38)

one participant. Seventy-six views were photographed by 2 or more participants on the northbound route and 85 on the southbound route. Among them, fifty views were photographed by 5 or more participants. On the northbound route there were 24 views spread throughout every landscape unit except Unit 6, with a large proportion (11/24 views) in the mountainous landscape units. On the southbound route there were 26 views, 12 of which were in the mountainous landscape units (Units 1 to 3); the remainder of views photographed were spread throughout some of the landscape units within the hills and the plain.

Embankments: number and location of retained images

The analysis of the images revealed that the vast majority were overall views and included three planes of view; 88% for the northern route and 92.6% for the southern route. The embankments were visible in the majority of these images: 64.2% of the images of the northern route and 72.5% of the images of the southern route. As previously mentioned, all images taken by each participant and containing embankments were included in a personalized questionnaire. Twenty-seven persons returned the questionnaires, providing information on 343 pictures.

Three distinct situations were revealed by these images (Table 3). In the first situation, embankment vegetation was circled, or the accompanying comment indicated clearly that it was the intended subject of the picture (27 images or 7.9%, by 33.3% of respondents). In the second situation, the embankment vegetation was circled along with other elements of the picture (102 images or 29.7%, by 88.9% of respondents). Finally, embankment vegetation was excluded from the

Table 3. Distribution of the intended subject in images with the embankment vegetation

Respondent	Embankments	Overall view	Other elements
01	0	6	6
02	0	0	8
03	0	9	5
07	0	3	14
08	0	5	2
09	0	2	2
10	1	6	7
12	1	2	5
13	1	1	5
14	0	12	4
15	0	3	8
16	8	4	9
17	2	1	8
21	0	3	12
22	5	9	7
24	0	1	10
25	0	2	8
26	0	1	10
27	0	4	11
28	0	0	8
29	0	0	14
31	0	4	7
32	1	3	15
34	6	4	12
35	0	2	0
36	0	11	8
37	2	4	9
Total	27 (7.9%)	102 (29.7%)	214 (62.4%)

circled element(s) (214 images or 62.4%, by 96.3% of respondents).

The embankment vegetation was circled - and thus considered as the intended subject of the picture - in 18 pictures, or 66.6% of cases, on the northbound route and in 9 pictures, or 33.3%, on the southbound route. The written comments provided the following detail: in some cases it was specifically blooming plants, which were appreciated (12 out of 24 images, or 50%), otherwise it was the general vegetation, blooming or not, which was appreciated (9 images or 37.5%), and in other cases it was the reed-grass colonies, which had captured the attention (3 images or 12.5%).

As for the second situation (102 images), in which the embankment vegetation was circled along with other elements of the picture, the images can be separated into four types, as follows:

a. overall views located in the hilly sections of the route where the visibility of the central or lateral embankment is increased because of the configuration of the road (25 images or 24.5%; type 1);

b. views of broad shoreline taluses, all with isolated trees or woodlots on top (18 images or 17.6%; type 2);
c. overall views in which the embankment vegetation blends in with that of an agricultural field (32 images or 31.4%; type 3); and
d. views in which the embankment is one composition element of several parallel layers (type 4), including either woodlot images (18 or 17.6%) or mountains in the second plane (9 images or 8.8%).

In the case of the third situation, in which embankment vegetation was excluded from the circled element(s) (211/343 images), the circled elements were, as follows:

a. mountains in the 2nd or 3rd plane, or in the background (111 images or 52.6%);
b. woodlots or isolated trees (34 images or 16.1%);
c. ski slopes (21 images or 10%); views of downtown Montreal from St-Jérôme (5 images or 2.4%);
d. agricultural fields (5 images or 2.4%); and
e. occasional varied elements such as billboards, animals, buildings, etc. (35 images or 16.6%).

Participants noticed a very small number of plant groups listed as part of the inventory of blooming areas. Fifty-five such colonies were identified for the northbound route and fifty-six for the southbound route. On the northbound route, only a few colonies of reed-grass (*Phragmites communis*) were photographed, with clusters of fireweed (*Epilobium angustifolium*) near St-Sauveur and clusters of black-eyed Susan (*Rudbeckia hirta*) near Val-Morin (eight pictures in all). Of the 56 plant formations identified on the southbound route, twelve images were taken by participants on the route; four images showed flowers on the central divider, three images showed clusters of fireweed (*Epilobium angustifolium*) on the outer bank, and five showed the embankment without capturing any particular flowering area.

Questionnaire results regarding ecological management

After a brief explanation of the terms *embankments* and *new management method,* the participants had to respond to the following question:

> *Have you noticed a change in the appearance of the embankment of Highway 15 North since the Provincial government began this new management method during the summer of* 2001?

Thirty-seven percent of respondents responded in the affirmative. They were then asked to identify the sector under ecological management. From the 27 respondents, 60% were able to correctly identify at least one part of the sector under ecological management (located between St-Jérôme and St-Jovite). The majority of these respondents, eight in 10, said that they appreciated the change a great deal; one in 10 had an average appreciation; and one in 10 did not appreciate it at all. Those respondents feared that "in the absence of pretty vegetation the roadsides will seem to be neglected" or that the embankments would be "less tidy."

DISCUSSION

The study obtained results, which were generally expected, regarding the appreciation of highway landscapes and the vegetation management on embankments. The general appreciation of highway landscapes, both in terms of quantity and quality of the images taken, tended to show that the scenery of the route was appreciated by users and offered specific characteristics able to arouse what Appleton calls "the spontaneous enjoyment of landscape" (Jackle, 1987, p. 35). In addition, the response rate to the additional questionnaire seems to confirm this interest in highway landscapes. The data obtained helped to clarify the contribution of embankment vegetation and ecological management towards the general appreciation of the landscape.

Appreciation of highway landscapes

The results of the photographic inventory indicate that the respondents residing in the Laurentians took a slightly larger number of photos than respondents residing in the metropolitan region, an average of 22.3 photos versus an average of 20.7 respectively, which does not represent a significant difference, and indicates that the appreciation of the route is not associated with residence location. Furthermore, we might have expected that regular users would take more photographs than occasional users, because of a greater knowledge of points of interest. The results show that even though they took a slightly higher number of photos, an average of 21 photos for regular users versus an average of 20.3 photos for occasional users, the difference is again not significant.

The analysis showed a marked appreciation for characteristic views of the two main landscape types on the route: the mountainous landscape and the rural/agricultural landscape. The images of mountains were numerous and a large majority of road images were taken in the hilly and mountainous sections of the route (89.1% for the northbound route, 88.5% for the southbound route; see Table 1). Examination of images show that, for the majority of road images, appreciation for the road itself is linked to the characteristic visual effects of a route in a mountainous region. These visual effects are created by topography (framed views, meandering effects) and short perspectives - mountains forming a wall directly in the axis of the road- and were frequently photographed in both directions. The images centred on the road, or axial views, taken by participants are thus inseparable from the mountainous setting, with only rare exceptions. Many photographs were also taken in the agricultural plain on both routes (Units 1 and 2 of the northbound route and units 12 and 13 of the southbound route). These images portray elements typical of agricultural activity: barns, animals or views of fields.

The rare views of the North River were frequently photographed. The appreciation of bodies of water has been revealed in many studies exploring landscape quality (e.g. Kaplan and Kaplan, quoted in Kent, 1995; Litton, quoted in Yamashita, 2002). It was therefore not surprising to find that participants photographed most landscapes containing water. What was far more surprising was the precision and the rapidity required of the participants in order for them to take some of these images. This seems to confirm the high aesthetic appreciation that people have for bodies of water.

These results seem to confirm the existence of certain landscapes that have qualities, which arouse an aesthetic appreciation, to the point that they become structuring elements in the landscape. Also, as was indicated earlier, many images were taken by a significant number of participants. This shows that those structuring elements are highly valued by a large number of users.

The objective of the photographic inventory was to obtain information on the most highly appreciated landscapes, as well as on the specific elements, which give them value. The analysis of the questionnaire shows that the participants easily distinguished between both types of representations during their inventory, because a significant number of images were taken with the purpose of recording a particular element (211 image of 343, or 61.5%), and not only general views. In fact, results suggest that the interest of this route is linked to the presence of structuring landscapes, but also to the presence of elements, which participate in a more occasional way to overall appreciation, with blooming plants on the embankments as part of this second category.

Embankments vegetation and the appreciation of highway landscapes

Few images centred directly upon the embankments were made. The analysis of questionnaire responses shows that participants sought to photograph embankment vegetation in less than one twentieth of the images taken (4.83% or 27 of the 559 images taken by the 27 respondents, or 6.55% for the route 1 and 3.17% for the route 2). The relative importance of vegetation in the foreground in the overall appreciation of the route is evidently low, in spite of the fact that the inventory has revealed the presence of patches of varied appearance in the vast majority of landscape units, which confirms the results obtained with the classification by types of views, being 2.0% of all images for route 1, and 3.2% for route 2 (see Table 1). But many more images included embankment vegetation as part of a general composition that was appreciated, which allows us to add nuance to a result, which appears negative at first.

As discussed previously, four types of views are revealed by a closer examination of the images where the embankment vegetation was circled with other elements of the picture (see Fig. 3), such as (1) images of a mountainous region, (2) of broad shoreline taluses, (3) of agricultural fields, and (4) in views of woodlots or mountains in which the embankment is one of several elements of a picture with parallel layers or planes. In the first type of views, the central embankment plays a particular role because it benefits from maximum visibility conditions caused by the configuration of the road (curve and ascension, curve and descent), and masks most of the opposite lanes of the highway. The embankment participates in the composition of an image whose planes are very clearly delineated. The second type of views, broad shoreline taluses, again allows maximum visibility for the vegetation. More than the herbaceous vegetation, it is the broad sloping shoreline talus topped by trees which seems to be appreciated by users. In views of fields (type 3), the embankment vegetation seems to be confused with that of the agricultural field. The short herbaceous plants and reed-grass colonies create a regular strip, similar in appearance to that of crops (grasses, corn), and the embankment seems incorporated by mimicry to a landscape composition. In the type 4 views, the embankment participates in the composition of vegetation layers, which are arranged in a manner pleasing to the eye.

The inventory produced reveals that, generally, the blooming plants of the embankments are not very visible, likely because of the visual constraints occurring during driving and because of the configuration of the road. This is particularly true for the vegetation of the interior embankments, often concave and thus more difficult to see. There can be exceptions, however. For example, fireweed colonies have good visibility characteristics (bright colour, a mass occupying a large area, location on the flank of a broad shoreline) and were noticed and appreciated by several participants.

The results show that embankment vegetation, under ecological management, does not contribute, in most situations, to the general appreciation of landscapes, unless their aesthetic quality is increased by design. The results, however, also show that in some specific situations they can contribute to the general appreciation. Because the visibility of the embankment is a predominant factor, eventual design interventions to improve embankment appreciation will have to take into account the question of visibility, and be based on the strategic deployment of blooming plants in relation to road configuration, and the use of plant compositions with sharp contrast. Because the visual effects of the composition of vegetation layers are also a predominant element in landscape appreciation, design interventions will also need to take into account the question of the composition of vegetation layers producing sharp and varied visual effects along the route. This could be done, for example, by seeding or planting native flowers and shrubs, which could also reinforce some regional characteristics of indigenous vegetation.

More importantly, for the management of highway landscapes, the combined analysis of all images and the results of the questionnaire suggest that landscape appreciation is more likely linked to wider views that travellers are able to see beyond the roadway. Appreciation of embankments is thus largely inseparable from that of the larger landscapes seen from the highway. Design and management measures of the vegetation of embankments must thus be modeled with respect to the characteristics of the second and third visual planes. A change in management inspired uniquely by vegetation on the embankments does not appear to be sufficient to attain the objectives announced by the Ministry of Transport of Quebec. The challenge lies in managing both the embankments and the greater context, as it implies coordination of many public and private stakeholders.

The future of the ecological management program

Does ecological management of roadside vegetation generate qualities, which are noticed and appreciated by users? There were so few images intentionally centred upon embankments that no direct inferences can be made about user appreciation of the two management methods. The results of the questionnaire, however, reveal that the close relationship between the user and the natural setting was greatly appreciated. Ecological management can decrease the perceived distance between the road and its more natural context, and facilitate the establishment of a pleasing connection between the natural setting and the user. We have seen that specific design measures could contribute to reinforce this connection. These could be accompanied with maintenance measures, like the scheduling of periodical mowing to favour the presence of blooming plants in strategic places or to maintain, or increase, the overall effect of the landscape composition. For instance, a fall mowing of the embankments located in the agricultural plain would be absolutely consistent with the harvest season. Many fields of research must make a contribution in order to facilitate the evolution of a more adequate management of highway corridors under ecological management. There is a need for better visual assessment methods in highway contexts, on the relative appreciation of landscape planes at high speed, to test the size of patches and the colour contrasts that actually capture the attention of travelers at various speeds, but also to study the appreciation of experiences that are linear and sequential in nature. There is also a need to improve roadway management that would take into consideration the sequential nature of routes and the specific regional "signatures" of indigenous vegetation.

Finally, the analysis of the results shows that they are applicable to contexts other than Highway 15 North, and even to contexts other than Quebec. On both routes, the participants photographed spectacular landscapes, or course, but also a large number of varied elements, of which many were "natural" elements. This leads us to believe that such natural elements can occupy a dominant place in routes, which are characterized by ordinary landscapes, and that design and maintenance measures can contribute to the improvement of the landscape experience in a multitude of highway landscapes.

CONCLUSION

The results obtained show that users appreciate roadway landscapes. The enthusiasm of participants, the general quality of the photographic inventory produced, and the comments and explanations given seem to reflect an interest in roadway landscapes in general, and for the particular aesthetic qualities encountered.

The results do not clearly confirm the hypothesis that embankment vegetation made a significant contribution to the aesthetic appreciation of Highway 15 North. Embankment vegetation rarely seemed to contribute to the general appreciation of the landscape, or even capture the attention of users. The results, however, did show that constituent parts of the natural setting have aesthetic qualities, which are appreciated by users, and that their proximity with the traveler next to the larger natural setting is greatly appreciated. The ecological management of highway corridors has therefore a role to play in the improvement of the overall quality of natural heritage and its associated aesthetic appreciation, and in the improvement of the general landscape quality seen from the roadway, as long as the management of embankments is closely linked to the management of the visible landscape of the region being traversed.

Beyond the specific case study, the results allow us to identify certain design and management rules, which are applicable to other contexts, and which are interrelated, in order to lead to a real management of highway landscapes, whose objectives are to reinforce the connection with nature, to increase the aesthetic qualities of the plant compositions, and to reinforce some specific visual effects and regional characteristics.

Finally, relating the characteristics of the highway landscape with its appreciation by its users contributed to the understanding of the aesthetic appreciation of a highway corridor, and of its different management methods. The relative simplicity of the research method used offers interesting possibilities for obtaining data, which can serve as the basis for redefining management methods aimed at the senses of users at all landscape scales, such as Quebec's and other highway networks.

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REFERENCES

Bédard, Y., D. Trottier, L. Bélanger, J.-P. Bourassa, J. Gérin-Lajoie, G. Lacroix, and E. Lévesque. 2000. Managing the Green Heritage of Quebec's Highways: A New Ecological Approach. In: Elsevier (Editor), Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Sept. 9–13, 2000, Calgary, Alberta, Canada, pp. 147–154.

Bédard, Y. and D. Trottier. 1999. Gestion de la végétation dans les emprises autoroutières: une nouvelle approche. In: Actes du congrès AQGV-SIAQ, Nov. 3–4, pp. 63–73.

Bissonnette, M., and S. Paradis. 2000. Management of Native Prairie Fragments on Canadian Pacific Railway Right-of-Way. In: Elsevier (Editor), Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Sept. 9–13, 2000, Calgary, Alberta, Canada, pp. 517–524.

Chenoweth, R. 1984. Visitor Employed Photography: A Potential Tool for Landscape Architecture. Landscape J., 3(2): 136–143.

Cherem, G.J. and B.L. Driver. 1983. Visitor employed photography: a technique to measure common perceptions of natural environments. J. Leisure Research, 15: 65–83.

Coumoul, H. and P. Chavaren. 1992. Guide d'entretien des dépendances vertes. Paris, Autoroutes du Sud de la France.

Dakin, S. 2003. There's more to landscape than meets the eye: towards inclusive landscape assessment in resource and environmental management. The Canadian Geographer, 47(2): 185–199.

Daniel, T.C. and M. Meitner. 2001. Representational validity of landscape visualizations: the effects of graphical realism on perceived scenic beauty of forest vistas. J. Environ. Psych., 21: 61–72.

Fischesser, B. and M.F. Dupuis-Tate. 1996. Le guide illustré de l'écologie. Paris, Ed. de la Martinière.

Gérin-Lajoie, J. and E. Lévesque. 2002. Suivi écologique: volet flore. Final report, preliminary version. Ministry of Transport, Quebec.

Hough, M. 1990. Out of Place: Restoring Identity to the Regional Landscape. Yale University Press. Houlet, J., 1993. Éléments pour une théorie du paysage autoroutier. Paris, Autoroutes du Sud de la France.

Houlet, J., 1993. Éléments pour une théorie du paysage autoroutier. Autoroutes du Sud de la France, Paris.

Jackle, J.A. 1987. The Visual Elements of Landscape. Amherst, University of Massachusetts Press. Kent, R.L., Elliott, C.L., 1995. Scenic routes linking and protecting natural and cultural landscape features: a greenway skeleton. Landscape Urban Planning, 33: 341–355.

Kent, R.L., Elliott, C.L., 1995. Scenic routes linking and protecting natural and cultural landscape features: a greenway skeleton. In Landscape and Urban Planning, 33: 341–355.

Lelli, L. 2000. Le paysage, un enjeu pour les acteurs territoriaux? Réflexion sur une démarche de connaissance et de médiation en Nord-Comminges (Haute-Garonne, France). In: Action paysagère et acteurs territoriaux. Périgord, M. (dir.), Poitiers, Université de Poitiers, GESTE (Groupe d'étude des sociétés, territoires et environnement), 19–26.

Meunier F., C. Gauriat, C. Verheyden, and P. Jouventin. 1998. Végétation des dépendances vertes autoroutières: influence d'un mode de gestion extensif et du milieu traversé. Revue d'écologie (Terre & Vie), 53(2): 97–121.

Michelin, Y. 1998. Des appareils photos jetables au service d'un projet de développement: représentations paysagères et stratégies des acteurs locaux de la montagne thiernoise. Cybergeo 65 (cybergeo.presse.fr/geocult/texte/michelin.htm).

Michelin, Y. 2002. Le paysage dans un projet de territoire – Démarche et méthode expérimentées en Limousin. Délégation à l'aménagement du territoire et à l'action régionale (DATAR), Ministère de l'équipement, des transports, de l'aménagement du territoire, du tourisme et de la mer (France).

Poullaouec-Gonidec, P. 1993. Trois regards sur le paysage de Verchères. Essai de caractérisation du paysage. Report, Ministry of Culture (Quebec).

Quebec, Ministry of Transport. 2001. Direction de Laurentides-Lanaudière. Vers un plan d'intervention sur les paysages du corridor de l'autoroute 15 et de la route 117. Caractérisation et évaluation des paysages (preliminary version).

Schaefer, V. 2000. Rights-of-Way Management in Support of Biological Conservation. In: Elsevier (Editor), Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Sept. 9–13, 2000, Calgary, Alberta, Canada, pp. 303–307.

Shannon, S., R. Smardon, and M. Knudson. 1995. Using visual assessment as a foundation for greenway planning in the St. Lawrence River Valley. Landscape Urban Planning, 33: 357–371.

Stewart, W.P., D. Liebert, and K.W. Larkin. 2004. Community identities as visions for landscape change. Landscape Urban Planning: 69(2–3): 315–334.

Taylor, J., K. Czarnowski, N. Sexton, and S. Flick. 1995. The Importance of Water to Rocky Mountain National Park Visitors: An Adaptation of Visitor-Employed Photography to Natural Resources Management. J Appl. Recreation Res., 20(1): 61–85.

The Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. 9–13 September 2000, Calgary, Alberta, Canada. Goodrich-Mahoney, Mutrie and Guild (Ed.), 2002.

Viles, R.L. and D.J. Rosier. 2001. How to use roads in the creation of greenways: case studies in three New-Zealand landscapes. Landscape Urban Planning, 55: 15–27.

Yamashita, S. 2002. Perception and evaluation of water in landscape: use of Photo-Projective Method to compare child and adult residents' perceptions of a Japanese river environment. Landscape Urban Planning, 62: 3–17.

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Vegetation Management of Aviation Rights-of-Way

Calvin W. Layton and Julia A. Stearns

Vegetation is a constant threat to Federal Aviation Administration (FAA) protected flight surfaces. As a matter of human safety these surfaces need to be kept clear just like all rights-of-way (ROW). This paper details the definition, analysis, and solutions to vegetative impacts at state airports in New England. Unlike most utility ROWs, airports encounter vegetation problems from grass to mature trees that interfere with protected surfaces. Vegetation has to be managed with techniques ranging from mowing to selective thinning of mature forests. FAA protected surfaces pose unique problems determining where the surface is, what areas are to be cleared and how, and how to illustrate the protected surfaces and their correlation to the determined clearing areas. A Geographic Information System (GIS) was used to analyze the difference between ground contours and the FAA surfaces. This analysis allowed for the development of compatible vegetation zones underneath the flight surfaces. A field survey of each airport was done to classify existing vegetation. This information was used in the creation of a Vegetation Management Plan using Integrated Pest Management principles to establish stable communities, which are important for improving and streamlining airport clearing management as well as decreasing disruptions to natural and sensitive resources. This integrated approach resulted in solving permitting problems with state environmental agencies, providing a cost effective solution for the funding agencies, and a long-term implementation plan for the airports.

Keywords: Integrated Vegetation Management, FAA, GIS, aviation, integrated pest management, ROW

INTRODUCTION

Vegetation is a constant threat to Federal Aviation Administration (FAA) protected flight surfaces. As a matter of human safety these surfaces need to be kept clear just like all rights-of-way (ROW). The major difference between an aviation ROW and a more traditional ROW is that the surface is invisible, but like most ROWs, if something breaks through the surface, the consequences can be grave. Just like driving on a highway where a clean unobstructed road and a clear view to drive is needed, a pilot needs an unobstructed path to take off and land an airplane. Likewise, if the car malfunctions and the driver has to pull off the road, a clear and unobstructed shoulder is needed to safely get off the road. Pilots also need a clear path to fly and in the event of a malfunction they need a clear path to abort a landing or take-off.

FAA regulations that define these protected surfaces are complex and have many variables. This paper presents a basic overview of the protected surface, required for the reader to understand the methods and concepts that are being put forth, as well as how vegetation impacts these surfaces. This paper also demonstrates the application of an Integrated Vegetation Management (IVM) program and techniques created in processes of designing an application that works for aviation protected surfaces.

The analysis methods that were developed to identify present and future vegetative impacts are an essential part of managing vegetation at airports. Without proper identification of these impacts a successful IVM program could not be implemented. Finally, solutions to vegetation impacts at airports flow naturally out of a good IVM strategy with proper analysis. This paper will demonstrate how the analysis and the IVM strategy depend on each other.

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J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

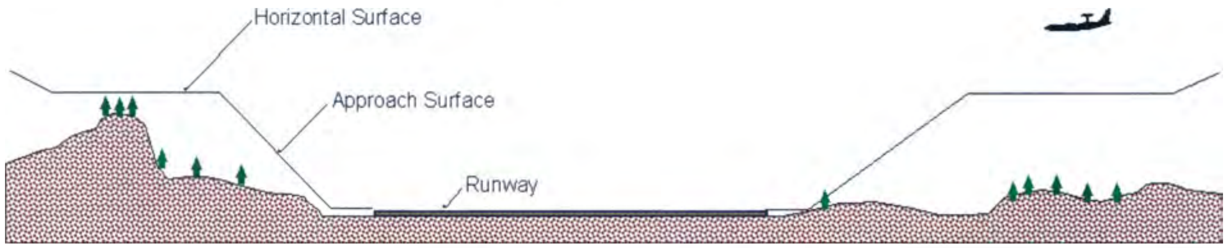

Fig. 1. Aviation protected surfaces diagram.

AVIATION REGULATIONS

FAA protected surfaces pose a unique problem in determining where the surface is located in correlation to the vegetation clearing areas. FAA is responsible for managing and protecting the national airspace system, and prescribing the extent of airspace (Federal Aviation Regulation). FAR Part 77 prescribes so-called protected surfaces, of which there are five in the vicinity of an airport (primary, approach, transitional, horizontal, and conical).

- **Primary Surface** - extends 200 feet beyond each end of a runway and has an elevation the same as that of the runway centerline. The width of a Primary Surface can vary from 125 feet to 500 feet from the centerline of the runway.
- **Approach Surfaces** - is applied to each end of a runway based on the type of approach available or planned for that runway end. If for example the inner edges of the Approach Surfaces can be the same width as the Primary Surface (250 feet) and can expand uniformly to a width of 1,250 feet. The Approach Surfaces will then extend for the horizontal distance, for example, 5,000 feet at a slope of 20 (horizontal) to 1 (vertical).
- **Transitional Surfaces** - extend outward and upward at right angles to the runway centerline, and the runway centerline extended, at a slope of 7 (horizontal) to 1 (vertical) from the sides of the Primary Surface and from the sides of the Approach Surfaces.
- **Horizontal Surface** - is a horizontal plane 150 feet above the established Airport elevation. The perimeter of the horizontal plane is constructed by swinging arcs of specified radii from the center of each end of the Primary Surface of a runway and connecting the adjacent arcs by lines tangent to those arcs. The radius of each arc is 5,000 feet for all runways designated as utility runways.
- **Conical Surfaces** - is a surface extending outward and upward from the periphery of the Horizontal Surface at a slope of 20 to 1 for a horizontal distance of 4,000 feet.

AVIATION VEGETATION MANAGEMENT

Most utility ROW's basically are linear with parallel surfaces that need to be kept clear of vegetation, like the side of highways, under power lines, or on top of pipelines. When the clearing surface is parallel to the ground the result is a consistent clearance specification. The FAA surfaces are varied in size, shape, and angle. Because FAA surfaces are sloping, vegetation clearance specifications can vary from grasses to mature trees. When combined with uneven topography the management of vegetation becomes complex. Identifying a specific clearing height at any point under the protected surface becomes essential in determining where, what type, and the timing of vegetation management.

A classic definition of IVM is as follows:

> "Integrated Pest Management (IPM) has been described as a system of resource management that attempts to minimize the interaction between the pest and the management system through the integrated use of cultural, biological, physical and chemical controls. Implementation of an IVM program utilizing modern ROW vegetation management techniques meets this definition completely; IVM is a system of resource (vegetation) management that minimizes interaction between the pest (tall growing trees) and the management-system (safe and reliable electric service) through the integrated use of cultural (mechanical and manual methods that physically remove tree stems), biological (low growing plants and herbivory), and chemical (herbicides) controls." (K. McLoughlin)

In applying the classic IVM strategy to an aviation ROW the "management system" becomes the protected surface. The survey and analysis methodology becomes a critical component of the management strategy.

Vegetation survey and analysis methodology

A Geographic Information System (GIS) was used to analyze the FAA protected surfaces in conjunction with topography as well as environmental data to determine what vegetation types were suitable to grow in specific areas, given the existing topography in relation to the parameters of the protected surfaces in those areas. Knowing that there are fixed distances between the ground surface and the protected surfaces, it was determined what height classes of vegetation are compatible with the surfaces.

To achieve the accuracy level necessary for this approach, it was important to have contour mapping for the entire Study Area that is as accurate as possible. Topographic information in the range of a meter plus or minus is sufficient. The ground elevation and the protected surfaces are the two "fixed points" in the equation, and the vegetation is the variable. Accordingly, this approach allowed us to quantify the variable, and through this process establish Vegetation Survey Areas (VSAs) for the airport.

An illustration of a VSA is demonstrated in the Fig. 2.

A VSA is an initial area of potential impact as determined in the analysis method and requires further field analysis to be verified. Field technicians (Foresters) surveyed the VSAs, determined forest types, even aged stands, and average tree heights. This field mapping of vegetation produced an inventory of the types and height classes of existing vegetation that underlies the protected surfaces. This inventory was used for development of a plan for converting incompatible vegetation into compatible vegetation within the protected surface. This conversion plan produced the Vegetation Management Zones (VMZs) that IVM strategy would recommend for compatible vegetation within the protected surface both on airport property and on properties surrounding the airport.

In conjunction with establishing and field verifying VSAs and VMZs, existing information was used to produce "Sensitive Resource" data layers for the areas of concern. This included using existing information for plotting all wetlands and watercourses within the study area. Plotted information was acquired from the Natural Diversity Database showing the locations of documented occurrences of listed species (Endangered, Threatened, Special Concern) and significant natural communities (e.g., vernal pools) in the study area. To complete the Sensitive Resource identification, available information on municipal surface water supplies, public wells, and FEMA 100-year floodplains in the study areas was plotted.

Once VMZs are established, field verified, and sensitive resources are mapped, vegetation removal methods were devised that would allow for the conversion of the existing vegetation into stable plant communities. This process provides both cost-effective and environmentally-sensitive methods for controlling incompatible vegetation.

Vegetation management methodology

A successful site survey and analysis will establish the size of the VSA and the height of the vegetation to be managed. These VSAs are analyzed and classified into

Fig. 2. Vegetation survey areas.

one of five VMZs which are designed to match the natural succession of plant species. Each of these zones will consist of vegetation that is desirable for the part of the protected surface that it is located under. Each VMZ will have an IVM strategy that fits into one of the following categories.

- **Zone 1** is the first zone off the Primary Surface. It is designated as a non-woody area consisting only of grasses and herbaceous plants with a maximum allowable height of three feet, see Fig. 3 below.
- **Zone 2**, the next zone away from the Primary Surface is designated as an area of low growing shrubs, such as sweet fern and low bush blueberries, with a maximum allowable height of ten feet, see Fig. 3 below.
- **Zone 3**, the third zone consist of tall growing shrubs, such as speckled alder and sweet pepperbush, with a maximum allowable height of thirty feet, see Fig. 3 below.
- **Zone 4**, the fourth zone is a small tree zone. The compatible vegetation will primarily consist of tall shrubs and small trees, such as smooth sumac and red cedar. Depending on soil and growing conditions, some taller trees may be allowed in the far end of this zone to increase vegetative diversity and enhance wildlife habitat. The maximum allowable height in this zone will be fifty feet.
- **Zone 5**, the fifth zone is a tall tree zone or native forest. Certain taller native species, such as white pine, may be culled out of the inner portion of this zone, but only as necessary. The maximum allowable height in this zone will be ninety feet.

When the principals of an IVM are applied to the unique constraints of each zone the result will be a changing management strategy. This demonstrates the flexibility and merit of a sound IVM approach to managing vegetation. The IVM objective is to manage vegetation in a sustainable, environmentally beneficial, cost-effective manner.

Vegetation Management Plan

A traditional IVM program uses five basic elements to evaluate the Vegetation Management Plan (VMP) and develop a sound strategy. The elements are preventive measures, biological controls, monitoring, assessment, and control measures. These essential elements of a sound IVM program are defined below.

Preventive measures

When land use on an airport ROW is utilized in a manner compatible with aviation facilities it naturally precludes the growth of non-compatible vegetation. The most common land use example would be various types of agriculture. In addition to these agrarian

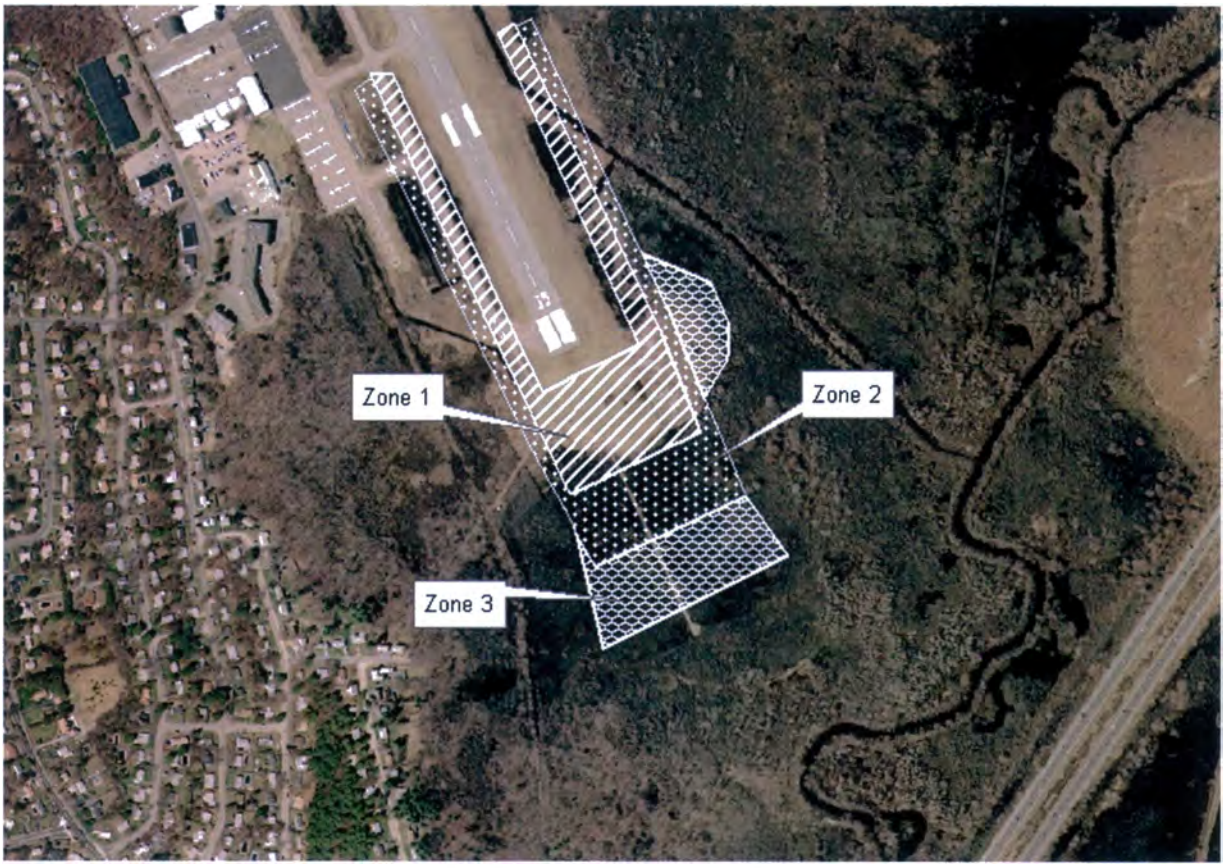

Fig. 3. Vegetation management zones.

Table 1. Typical compatible vegetation species within each VMZ

Zone 1. Herbaceous Species and Low Woody Ground Covers (1 ft. to 3 ft.)			
Woolgrass	*Scirpus cyperinus*	FACW	Moist to wet sites
Bluejoint Grass	*Calamagrostis Canadensis*	FACW	Moist to wet sites
Tussock Sedge	*Carex stricta*	OBL	Wet Sites
Large Cranberry	*Vaccinium macrocarpon*	OBL	Moist to wet sites
Reed Canary Grass	*Phalaris arundinacea*	FACW	Dry to wet sites
Little Bluestem	*Schizachyrium scoparum*	FACU	Dry to moist sites
Red Fescue	*Festuca rubra*	FACU	Dry to moist sites
Switchgrass	*Panicum virgatum*	FAC	Dry to moist sites
Zone 2. Woody Shrubs of Low to Medium Stature (3 ft. to 10 ft.)			
Sheeplaurel	*Kalmia angustifolia*	FAC	Dry to moist sites
Sweet Fern	*Comptonia peregrine*	UPL	Dry to moist sites
Meadowsweet	*Spiraea latifolia*	FAC+	Most to wet sites
Steeplebush	*Spiraea tomentosa*	FACW	Moist to wet sites
Bayberry	*Myrica pensylvanica*	FAC	Dry to moist sites
Lowbush Blueberry	*Vaccinium pallidum*	UPL	Dry sites
Late Lowbush Blueberry	*Vaccinium angustifolium*	FACU	Dry sites
Inkberry	*Ilex glauca*	FACW	Moist to wet sites
Virginia Rose	*Rosa virginiana*	FAC	Dry to moist sites
Swamp Rose	*Rosa palustris*	OBL	Wet sites
Common Huckleberry	*Gaylussacia baccata*	FACU	Dry sites
Dangleberry	*Gaylussacia frondosa*	FAC	Dry to moist sites
Silky Dogwood	*Cornus amomum*	FACW	Moist to wet sites
Zone 3. Woody Shrubs of Medium to Tall Stature (10 ft. to 30 ft.)			
Highbush Blueberry	*Vaccinium corymbosum*	FACW	Moist to wet sites
Common Elderberry	*Sambucus Canadensis*	FACW	Moist to wet sites
Speckled Alder	*Alnus rugosa*	FACW	Moist to wet sites
Witch-Hazel	*Hamamelis virginiana*	FAC	Dry to moist sites
Spicebush	*Lindera benzoin*	FACW	Moist to wet sites
Purple Chokeberry	*Aronia prunifolia*	FACW	Dry to moist sites
Sweet Pepperbush	*Clethra alnifolia*	FAC+	Moist to wet sites
Common Winterberry	*Ilex verticillata*	FACW	Moist to wet sites
Arrowwood	*Viburnum dentatum*	FAC	Dry to moist sites
Witherod	*Viburnum cassinoides*	FACW	Dry to moist sites
Zone 4. Small Trees and Tall Shrubs (30 ft. to 50 ft.)			
Gray Birch	*Betula populifolia*	FAC	Dry to moist sites
Pussy Willow	*Salix discolor*	FACW	Moist to wet sites
Bebb Willow	*Salix bebbiana*	FACW	Moist to wet sites
Eastern Red Cedar	*Juniperus virginiana*	FACU	Dry sites
Smooth Sumac	*Rhus glabra*	UPL	Dry sites
Staghorn Sumac	*Rhus typhina*	UPL	Dry sites
American Holly	*Ilex opaca*	FACU	Dry to moist sites
Zone 5. Medium to Tall Trees (50 ft. to >90 ft.)			
Red Maple	*Acer rubrum*	FAC	Dry to wet sites
Tupelo	*Nyssa sylvatica*	FAC	Moist to wet sites
Yellow birch	*Betula allegheniensis*	FAC	Dry to moist sites
White Pine	*Pinus strobes*	FACU	Dry to moist sites
Scarlet Oak	*Quercus coccinea*	UPL	Dry sites
White Ash	*Fraxinus Americana*	FACU	Moist to wet sites

activities other types of allowable industrial commercial and residential multiple uses would be considered a preventive measure.

Biological controls

One of the major objectives of IVM is to promote stable plant communities, which consists of numerous species of woody and herbaceous plants. These low growing plant communities inhibit both tree establishment and the subsequent growth by directly competing with the species for the available site resources of sunlight, water, and nutrients. They also hinder tree seed germination and the early development of small tree seedlings, acting as biological control agents. (Bramble)

Monitoring

An IVM program calls for monitoring VMZs through routine inspection to determine overall program effectiveness as well as the current condition of the area.

This is to determine when the next treatment should occur and by what means. A critical component of an IVM program is that field inspections should be performed by professionals knowledgeable in identifying the undesirable tree species. These inspections also serve as a very important quality control and quality assessment function of the program.

Assessment

The potential for undesirable vegetation to grow into the protected surface has to be assessed to determine the most opportune time to implement control procedures. For airports, the opportune time is well before target trees reach the height of the protected surface. The assessment procedure is critical due to varying heights in the different VMZs, for example in the low end of the protected surface, you will be mowing grass while at the far end of the surface you maybe on a twenty year cycle of selective thinning of the forest.

Control measures

The vegetation manager has three basic tools to control vegetation, mechanical, chemical, and cultural. For each of these tools, there are different options available. For example, in Zone 1 grass/herbaceous areas can be mowed once or twice a year to maintain their non-woody state. Zones 2 and 3 are shrub zones and lend themselves well to selective chemical applications to keep them free of tall growing trees. Zone 4, small trees, can be maintained with a combination of mechanical cutting, chemical stump treating, and some selective chemical applications. In Zone 5, tall trees, mechanical methods of selective thinning the tallest trees are carried out on a cyclical basis and chemical stump treating typically is not cost effective. All of these zones can be candidates for cultural controls. Some airports have effectively converted areas to pastures for grazing or have developed land for industrial purposes. (Johnstone)

SUMMARY

IVM is a proven methodology that has been used for managing vegetation on rights-of-way for over fifty years. By apply this tool to aviation rights-of-way airport facilities are provided with a tested tool for managing vegetation penetrations to their protected surfaces.

The survey and analysis part of the project provides a permanent map of what heights vegetation can be allowed to grow to at any point under the protected surface. This is a great tool for vegetation managers given the complexity of the surfaces over the uneven topography often found in New England.

The IVM strategy would have been very complex to implement for aviation rights-of-way without the GIS analysis. This analysis has many other benefits in addition to implementing the IVM strategy. The vegetation map generated by the analysis shows the VMZs and becomes the basis for interacting with the environmental community, the regulatory community and the airport abutters.

Many airports have environmental issues that have attracted the attention of non-governmental environmental advocacy groups such as Nature Conservancy or Audubon. A scientifically based management plan along with the supporting documents and maps helps create a good working relationship with these stakeholders while achieving a safe aviation environment.

This integrated approach can also result in solving permitting problems with state environmental agencies. The IVM benefit of increased bio-diversity, control of invasive plant species, and large areas of stable vegetative communities is a desirable environmental outcome. Vegetation managers can work with the agencies to design a proper selection of plant species to address certain bio-diversity issues such as rare and endangered species. It also provides a cost effective solution for the funding agencies, and a long-term implementation plan for the airports. (Young)

Traditional airport clearing methods often use large mechanized mowing equipment and can be a source of controversy with airport neighbors. Good relations are a very important part of operating an aviation facility. With a good IVM plan concerned abutters have confidence that the airport has a long-term plan for vegetation management and eliminates disruptive clearing practices.

The methods developed in this paper will result in the successful implementation of an aviation IVM program allowing airports to benefit from the many desirable outcomes of proper vegetation management.

REFERENCES

FAA AC 150/5100-16A – Airport Improvement Program Grant Assurance Number One – General Federal Requirements, para. 20. Hazard Removal and Mitigation.

Federal Aviation Regulation (FAR) Part 77 (14 CFR 77), Objects Affecting Navigable Airspace (FAA AC).

McLaughlin, K.T. 1997. Integrated Pest Management to Electric Utility Rights-of-Way Vegetation Management in New York State, Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-way Management, Elsevier Science Ltd.

McLaughlin, K.T. 2000. Integrated Vegetation Management The Exploration of a Concept to Application, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-way Management, Elsevier Science Ltd.

Bramble, W.C., W.R. Byrnes, and R.F. Hutnik. 1990. Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way. Journal of Arboriculture, 16: 130–135.

Johnstone, R.A., M.R. Haggie, and H.A. Allen Jr. 2002. Tree, Shrub, Herb Succession and Five Years of Vegetation Management Following the establishment of a New Electric Transmission Right-of-Way through a Mixed Woodland, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-way Management.

Young, R.F. and E.J. Glover. 2002. Planting Shrubs for the Creation of Sustainable Power Line Rights-of-Way, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-way Management.

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Part III
Project Planning

Managing Environmental Compliance: A Study of Expansion, Replacement and Integrity Projects

William F. McCarthy

Environmental compliance for pipeline activities is subject to varying degrees of regulatory oversight. Case studies are presented that compare and contrast the strict and closely regulated mandates of mainline expansion with the rather subjective and often self-regulated activities typical of operations and maintenance efforts including pipeline integrity projects. These examples will demonstrate why the type of activity and project location are often the defining factors when assessing the applicable regulatory framework for a given project. Often when undertaking operations and maintenance activities pipeline operators must satisfy multiple regulatory agencies and thereby manage specific compliance issues by activity or agency based upon a subjective interpretation of available regulatory guidance. Therefore, the environmental staff at pipeline companies must be well versed in a wide range of environmental rules and regulations to discriminate between regulated and unregulated activities and prepare environmental compliance measures appropriately. By example it is demonstrated why project size and cost are less significant factors when evaluating compliance issues. A minor interconnect project may require a full FERC filing and proceedings, whereas a large-scale coating repair project may be relatively unregulated and is not subject to FERC oversight. However, a seemingly unrelated issue, such as workspace requirements can ultimately determine the compliance measures mandated by agencies. Case studies are presented to highlight these points while demonstrating some of the various regulatory scenarios for common pipeline activities including expansion, FERC 2.55(b) replacement, FERC Blanket Certificate replacement and pipeline integrity projects.

Keywords: FERC, 2.55(b), blanket certificate, replacement, integrity management, operations and maintenance, environmental compliance, ROW

DETERMINING REGULATORY REQUIREMENTS

The first step when formulating a strategy to maintain environmental compliance for any type of pipeline activity begins with a thorough review and understanding of jurisdictional limits and responsibilities of all potential regulatory agencies. The primary goal of this exercise is to determine if a single regulatory authority will assume the role of "lead" and thus shoulder much of the responsibility establishing compliance criteria and inter-agency coordination (Fig. 1). Most often agencies who assume lead responsibilities have federal authority (e.g., the Federal Energy Regulatory Commission (FERC), U.S. Army Corps of Engineers (COE), Bureau of Land Management (BLM), U.S. Department of Agriculture (USDA), or U.S. Coast Guard (USCG)) though states may assume the lead role for larger scale, intra-state projects. Typically agencies who take the lead will also prescribe the required components (e.g., consultations, surveys, implementation or mitigation plans) of compliance measures on a project-wide basis. As an example, the FERC has assumed this role in various public energy sectors including interstate transmission of natural gas. The FERC environmental review process is well established and their regulations have been codified. To enhance industries' understanding of the FERC process this agency offers supplemental guidance and on occasion will hold workshops to train the public on how to satisfy these standards.

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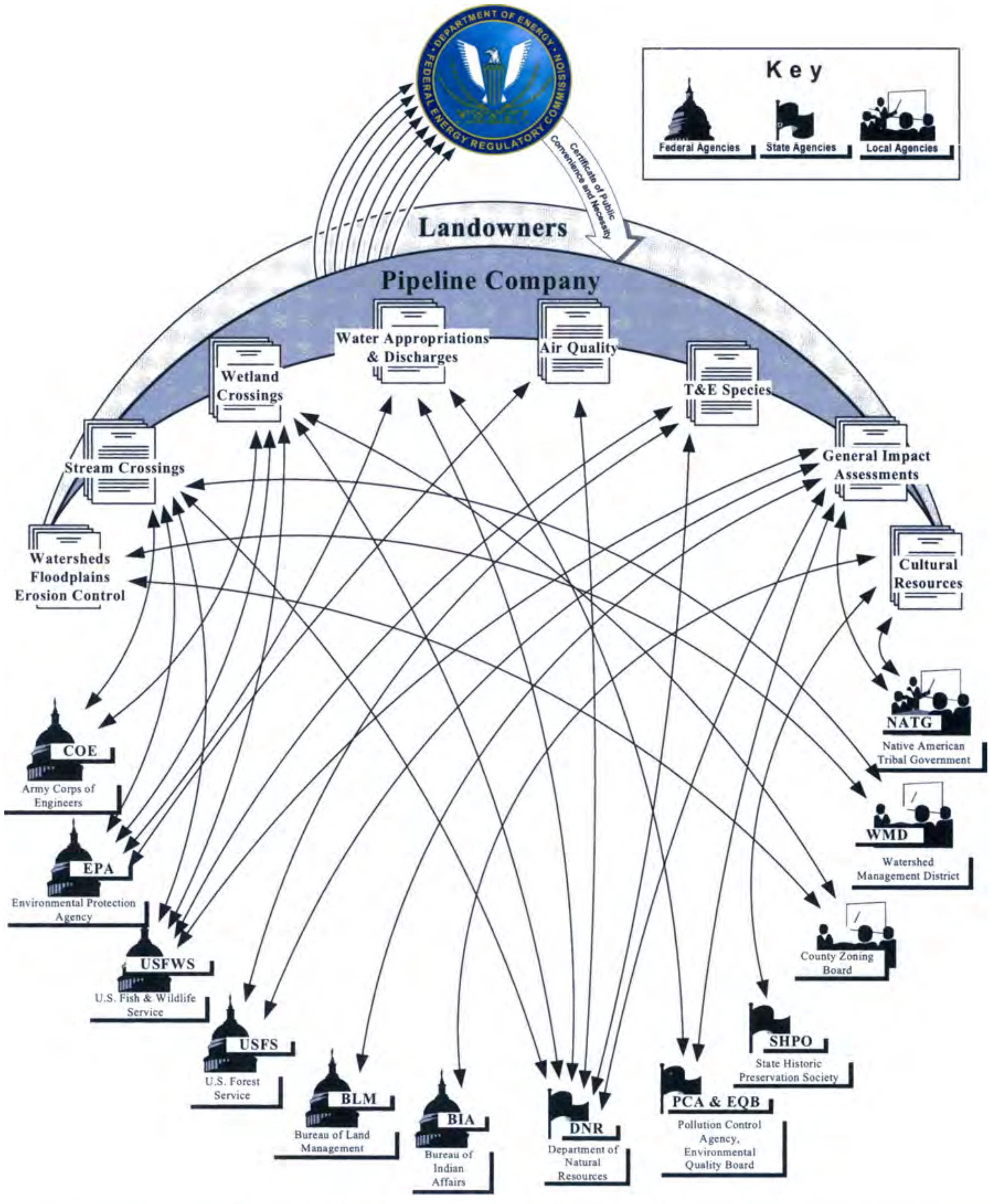

Fig. 1. Conceptual schematic depicting the role of a lead agency (FERC) with respect to jurisdictional authorities and environmental permits related to the construction of natural gas pipelines.

Conversely, when crude oil, liquids or product pipeline operators initiate projects the project sponsor assumes a greater responsibility of determining environmental compliance criteria as is also the case when interstate natural gas pipeline companies conduct activities that are not subject to FERC authority. In these circumstances, it is critical that pipeline operators and project sponsors fully understand jurisdictional limits of each agency in order accurately discriminate between federal, state or local authority in the absence of codified guidance and structure offered by a lead authority. Ultimately it becomes the project sponsors responsibility to ascertain "why" an agency permit or approval is relevant to a given situation.

A project sponsor must evaluate key project characteristics when assessing regulatory requirements. In most instances the initial triage will involve answering the following questions:

- The nature of the project (e.g., new construction versus operations and maintenance).
- Landownership in the project area (e.g., public versus private).

- Environmental site characteristics (e.g., wetlands, streams and natural areas) and anticipated air emissions, water appropriations and discharges, as well as the extent of ground disturbance.

Furthermore, construction techniques and project timing are "ingredients" of a well rounded regulatory strategy as they have the potential to influence some agency roles. A series of case studies will be utilized to demonstrate the influence that select environmental issues have on determining compliance strategy.

PIPELINE OPERATIONS, MAINTENANCE, AND INTEGRITY ACTIVITIES

Pipeline operators conduct a wide range of operations and maintenance (O&M) activities, such as line lowering, stream bank restoration and facility upkeep. In response to recent rule changes regarding pipeline integrity originating from the Department of Transportation's (DOT) Office of Pipeline Safety (OPS), many pipeline operators are now conducting an increasing number of pipeline inspection and repair projects. In general, environmental compliance standards for O&M activities including typical integrity activities are the same for all pipeline operators (e.g., crude oil, liquids, products, and natural gas). Typically, environmental issues for common O&M activities and DOT repairs are narrowly defined, often on an agency by agency basis. In these situations the pipeline operator assumes a greater responsibility for defining compliance. Depending upon the environmental characteristics of the project area, compliance may range from the simple implementation of standard best management practices (BMPs) up to multiple permits, consultations, surveys, mitigation and avoidance measures.

Individuals responsible for prescribing compliance measures for DOT mandated repairs and many other O&M activities continually walk the fine line between being too conservative and imposing unnecessary constraints versus being too liberal and risking exposure to non-compliance situations. The pipeline operator has many tools to draw upon when designing a compliance strategy. The internet provides instant access to permits, rules and conditions allowing the pipeline operator to make informed decisions. Information can also be obtained by utilizing consultations and or field surveys to define the jurisdictional limits of regulatory authority. Exemptions also have the potential to play a key role when addressing compliance, however, exemptions are often more appealing than they are useful. The rules defining compliance are rarely absolute; most often the rules leave room for interpretation. When working within rules that are subject to interpretation, a consistent interpretation is a readily defended position. Complete documentation of internal environmental reviews for O&M activities will further enhance credibility particularly when compliance decisions rely upon interpretations.

Case history: pipeline integrity activities

DOT mandated integrity management programs are challenging pipeline operators across the continent. Engineering departments have several methods of assessing pipeline integrity each of which present a varying degree of challenge regarding environmental compliance. Integrity testing covers a range of activities from the rather benign smart tool runs and in-line inspections to hydrostatic testing or even direct assessments. While integrity testing activities, such as hydrostatic testing, pose a rather modest compliance challenge, the subsequent repairs may introduce environmental compliance challenges that are both formidable and complex. Common integrity repairs are analyzed below.

Pipeline recoating and non-invasive integrity repairs

Environmental compliance for pipeline recoating as well as other typical non-invasive integrity repairs can be successfully addressed on a site specific basis by addressing regulated activities on an agency specific basis. These are common construction permits and approvals that may include land management agencies (e.g., BLM, NF or SF), wetland regulations, and water discharges (e.g., National Pollutant Discharge Elimination System (NPDES) regulated discharges including hydrostatic test water, storm water and possibly trench water) to name a few. Natural gas pipeline operators, however, are not required to obtain approval or report such activities to FERC. As such, a pipeline operator could find itself engaged in a rather large scale yet relatively unregulated recoating project, for example. Specifically, consider such a project involving several miles in total length that occurs entirely on private lands, with no involvement of wetlands or waterbodies; the only regulated activity requiring environmental compliance measures would originate from the National Pollution Discharge Elimination System rules due to total ground disturbance exceeding non-regulated thresholds.

Workspace constraints typical of FERC regulated activities do not apply to this type of project. The following list describes some common integrity type O&M activities that may be conducted without FERC oversight:

- Pipeline coating inspection and repairs (e.g., recoating).
- Direct assessments for DOT integrity management.
- Hydrostatic testing.
- Sleeving and casing installation and repairs.

Cathodic protection, anode beds and test leads

A case study of cathodic protection systems and more specifically anode bed installations provides an excellent opportunity to simplify the study of environmental compliance particularly for natural gas pipeline operators regarding a non-FERC regulated activity. By definition, these systems and their components are

Table 1. Anode bed scenarios

Environmental conditions	Landownership	Environmental compliance
Upland	Private	Unregulated (provided ground disturbance does not exceed NPDES storm water thresh holds)
Wetland associated with waters of the U.S.	Private	Wetland permitting US COE Nationwide Permits Standard and regional conditions State wetland review
Isolated Wetland	Private	Wetland permitting State agency State conditions
Upland	Public Lands e.g., BLM, USDA – NF or DOI – USFWS	Special Use Permit Internal Scoping by agency Environmental Review (possible cultural and/or biological surveys) Public Notice Decision document

non-FERC jurisdictional facilities for existing pipeline systems. For this case study, it is assumed that a pipeline operator is seeking to enhance the cathodic protection (CP) of its system through the installation of typical CP components (e.g.; power supply, cables, rectifier and anode bed) and determines that the configuration of the anode bed would be most effective if placed perpendicular to the pipeline while extending 1200 feet from the right-of-way (ROW). In this instance, the regulatory outcome is largely influenced by environmental conditions (e.g., wetlands versus uplands) and landowner considerations. For example, if this installation was to occur in an entirely upland location on private lands the activity is essentially unregulated. The same example, again entirely upland, but placed on federally managed lands, will likely result in a National Environmental Protection Act (NEPA) review. Table 1 outlines how common environmental conditions and landownership can influence the roles of various agencies and potential compliance measures with respect to non-FERC regulated activities.

Launchers, receivers and auxiliary piping

Across the industry, launchers and receivers (traps) are being installed where they were once absent. Many older systems require modifications of their existing facilities to accommodate the newest smart tools. These activities are also exempt from FERC jurisdiction and reporting requirements by definition under 2.55(a).

REPLACEMENTS

The environmental regulatory requirements governing pipe replacements are various and potentially confusing. Operators of crude oil, liquids and product lines may require authorization from state routing agencies to install replacement segments outside the existing ROW or state utility commissions, if replacements modify capacity. In contrast, replacement activities involving natural gas systems are more closely regulated, therefore, the various roles that FERC assumes with respect to pipe replacement activities warrants further analysis. To further illustrate this point, the following discussion contrasts FERC's role in various types of natural gas pipeline replacement projects.

Generally, when replacements result in changes in capacity or require additional ROW the prescription for compliance will be defined by FERC under the blanket certificate (CFR 18 Part 157(F).208) or possibly require more formal review process and 7(c) (CFR 18 Part 157(A)) filing. "In kind" replacements, however, which result in no change in capacity and occur within the existing ROW can be accomplished in full compliance, with little or no regulatory oversight from FERC, by exercising provisions and exemptions offered exclusively to maintenance activities, as defined by CFR 18 Part 2.55(b).

In order to develop an environmental compliance strategy for replacement activities, project sponsors must be prepared to define the project in terms of 1) capacity (e.g. increased capacity or in-kind replacement), 2) workspace requirements, and 3) ROW requirements (e.g. utilizing existing versus placement of replacement segments beyond the limits of the existing ROW).

Capacity in terms of replacement projects

Projects that alter pipeline segments and modify capacity (i.e., increase, decrease or abandonment of service) or result in a change of service (delivery or receipt) do not qualify under 2.55(b). Projects involving changes in capacity in conjunction with replacement activities require further evaluation to determine if the project qualifies under the Blanket Certificate (§157.208) or will require a 7(c) filing.

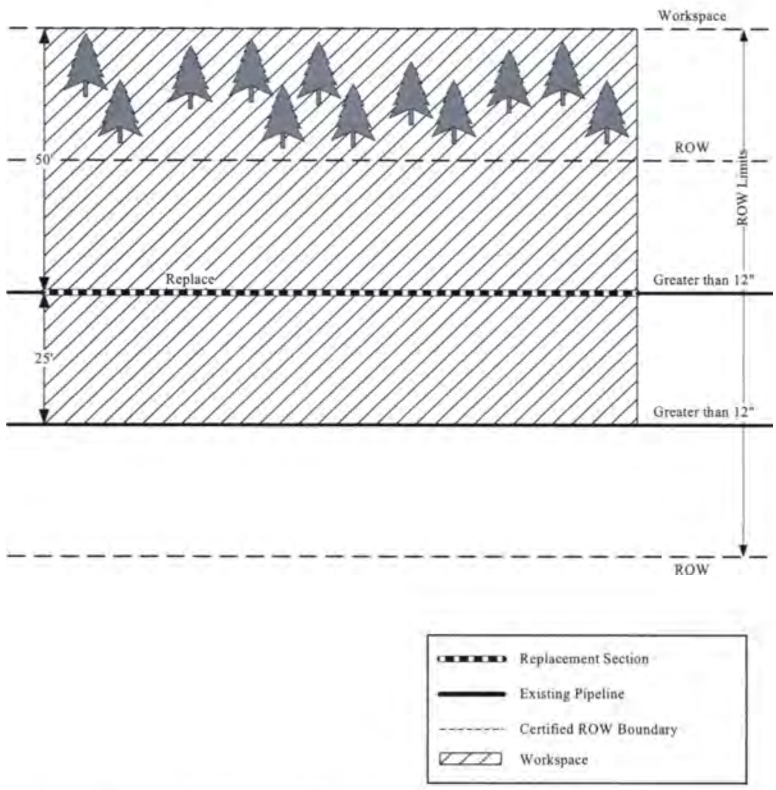

Fig. 2. Workspace that conforms with CFR 18 Part 2.55(b) conditions cannot disturb areas not previously disturbed by original construction. In this example, although the work space depicted conforms dimensionally – it does not conform relative to the orientation of workspace (working side); resulting in the workspace encroaching into previously undisturbed areas.

Case history: 2.55(b) pipe replacement analysis

By definition, certain replacement activities are *exempt* from the Natural Gas Act (NGA); exempt projects that conform to the conditions of 2.55(b) are *reported* to FERC *but are not subject to FERC environmental review.* Qualified 2.55(b) replacement activities are constrained by two key factors: 1) replacement sections must be installed within the original certificated ROW and 2) qualified workspace is limited by definition (for a complete listing see Appendix A of Part 2 CFR 18). Provisions within 2.55(b) guidelines, however, do allow the utilization of non-conforming workspace that was used during the original installation provided appropriate documentation can be produced (see below). As defined by rule and described in Appendix A to Part 2 of CFR 18, when appropriate documentation is lacking, replacement activities may utilize the following workspace areas:

- The construction workspace is limited to no more than 75 feet (total) including the permanent right-of-way for large diameter pipe (i.e., >12 inches in diameter) or 50 feet including the permanent right-of-way for small diameter pipe.
- The temporary workspace (working side) utilized during replacement shall be consistent with that utilized for the original installation (Fig. 2).
- Temporary extra workspace associated with feature crossings (e.g. road bores, stream crossings and rail road crossings) have also been standardized and defined.

Finally, two key considerations must not be overlooked when assessing qualified workspace. First, if the physical conditions within the replacement area suggest that it was not utilized for the original installation it does not qualify for workspace to be utilized for 2.55(b) activities (Fig. 3). Secondly, workspace utilized for the installation of an adjacent pipeline does not qualify for 2.55(b) activities (Fig. 4).

Utilizing documented non-conforming workspace for 2.55(b) replacements

Pipeline companies have the opportunity to utilize non-conforming workspace when conducting replacements under 2.55(b) provided it was used during the original installation and appropriate documentation can be produced. Non-conforming workspaces may include atypical temporary extra workspaces associated with common feature crossings, such as stream crossings, side slopes or foreign line crossings (Fig. 5).

Although not defined by rule, it would be safe to assume that proper documentation for these non-conforming workspaces would include FERC authorized variance requests or cultural resource survey coverage and related agency consultations related to "no effect" determinations. The quality of these records can influence the compliance strategy since the defense of marginal documentation in the post project

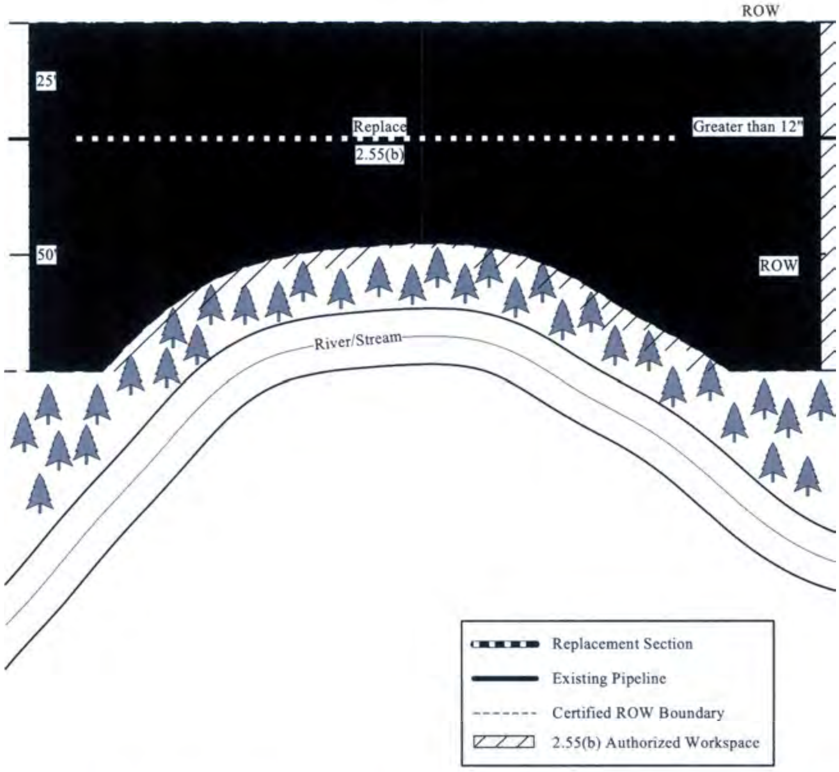

Fig. 3. Workspace that conforms with CFR 18 Part 2.55(b) conditions that is further constrained by physical evidence that an area has not been previously disturbed.

phase may be more onerous than defining the area of potential affect and managing the replacement under the blanket certificate. Project sponsors lacking quality documentation would be well served to consult directly with the FERC to discuss the suitability of alternative documentation.

Advanced notification requirements

Projects that qualify under 2.55(b) are obligated to provide *advance notification* (not to be confused with a *prior notice*) to the FERC thirty days prior to project initiation when defined cost thresholds are exceeded (unless the replacement is mandated immediately by DOT rules). *Advance notification* is required when project total costs exceed the limits established by rule (e.g.; 2003 reporting threshold was $7,600,000 USD). *Advance notifications* cannot be challenged (by interested third parties) and do not result in a FERC authorization.

Case history: FERC blanket certificate (157.208) replacement

Pipeline operators have the option to conduct pipe replacements under the blanket certificate. In contrast to 2.55(b) replacements that limit authorized work space (by definition), projects authorized under 157.208 allow the project proponent to define required work space on a project specific basis. This relative freedom from workspace constraints does not mean that the project proponent is free from obligations. The project sponsor must demonstrate that the proposed activities within the project site (or area of potential effect) conform with various legislated environmental policies including (but not limited to) National Historic Preservation Act (NHPA) and the Endangered Species Act (ESA) through "no effect" determinations from State Historic Preservation Officer(s) (SHPO), United States Fish and Wildlife Service, and when appropriate Tribal Historic Preservation Office(s).

In addition to landowner notification requirements, project sponsors are also obligated to file replacement activities conducted under the blanket certificate with FERC either in the *annual report* or as a *Prior Notice* activity. Replacement projects completed under the blanket certificate are also regulated in scope through incremental cost-based thresholds. To be eligible for automatic authorization, project cost cannot exceed $7,600,000 USD (effective through 2003). Projects conforming to cost constraints stipulated by automatic authorization may proceed when all other regulatory obligations, agency consultations and land owner notification requirements are satisfied. These projects are filed with FERC at a later date in the *annual report*.

Blanket replacement projects that range in cost from $7,600,000 to $21,200,000 (USD), must be filed with FERC as a *Prior Notice* undertaking. Environmental documents are filed, a docket number is assigned, and it is posted in the Federal Register for a standard 45 day public comment period. Projects that complete the comment period without challenge are authorized to proceed. Projects that are challenged will be processed

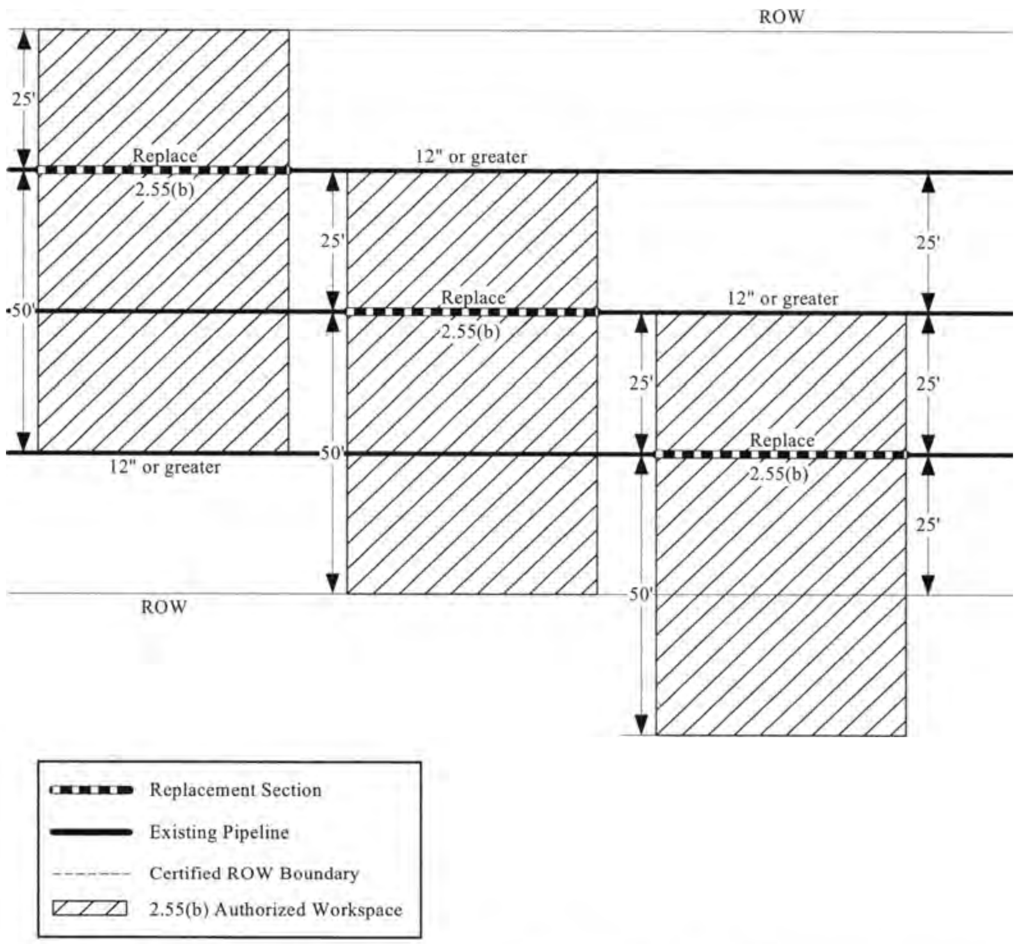

Fig. 4. Workspace utilized for replacement activities under CFR 18 Part 2.55(b) is limited to the construction workspace associated with the original installation of the replacement segment.

as Natural Gas Act (NGA) Section 7(c) filing. Projects that cost more than $21,200,000 (USD) are required to be filed under Section 7(c).

NEW CONSTRUCTION – PIPELINE EXPANSION

Pipeline activities involving expansion, modifications to capacity (increase or decrease) or delivery points are conducted in a generally closely regulated environment. Operators of crude oil, liquids, and product pipeline systems seeking to expand or modify the capacity of a system typically are required to obtain authorization from the equivalent of a state public utilities commission and as such the terms and conditions vary by state. Similarly, operators of natural gas systems must negotiate the highly structured environment of FERC jurisdiction under the authority of the NGA. The scope of the activity will largely dictate the formality of project review process and ultimately the type of authorization required. FERC authorizations range from blanket certificates to project specific certificates of public necessity. Pursuit of required FERC authorization may include a wide range of reporting/filing requirements from simple blanket certificate annual report filing to project specific proceedings involving exhibits, environmental reports, Biological Evaluations, or Environmental Impact Statements (EIS). The specifics of FERC environmental review for new construction are codified in detail within FERC regulations. While a thorough analysis of FERC's role with respect to new construction, is beyond the scope of this analysis, it can be generally inferred from the structure of the rules that it is the intent of FERC to impose oversight in a manner that is scaleable, yet thorough. While FERC generally assumes the role of lead agency for new construction, it is noteworthy that it does delegate its authority to project sponsors for consultations (e.g., NHPA and ESA). Also, while FERC's review is prescriptive in nature, it remains the project sponsor's responsibility to identify and comply with all other applicable federal, state and local environmental requirements. The examples detailed below will be utilized to compare and contrast key components of this process as they relate to interstate gas pipeline activities.

Certificates of public convenience and necessity

Large scale projects are required to navigate through a highly structured and closely regulated process to achieve the required certificate to authorize construction. The entire process has been codified (Code of

Table 2. Replacement activities: a comparison of constraints by regulatory authority

Natural Gas Act/1		Constraints				Comments
Authorization	Reporting/Filing	Capacity	ROW	Project scope (million USD)	Workspace	
2.55(b) (NGA Exempt)	Annual Report	In-kind	In-kind	<$7.3	Defined by rule	Qualified projects proceed without FERC oversight.
2.55(b) (NGA Exempt)	Annual Report Advance Notice (30-day)	In-kind	In-kind	>$7.3	Defined by rule	Qualified projects proceed without FERC oversight at the end of 30-day Advance Notice.
Blanket Certificate (157.208)	Annual Report Automatic Authorization	Any	Any	<$7.3	Specified by Project Sponsor	Immediate FERC authorization for qualified projects.
Blanket Certificate (157.208)	Annual Report Prior Notice (45 day)	Any	Any	$7.3 to $21	Specified by Project Sponsor	FERC authorization upon completion of Prior Notice provided no challenge(s) received.
Blanket Certificate (157.208)	Annual Report Prior Notice (45 day)	Any	Any	$7.3 to $21	Specified by Project Sponsor	Projects that receive challenge from interested an interested party shall be processed under the 7(c) review process.
Certificate of Public Convenience and Necessity (Section 7(c))	Section 7(c) application	Any	Any	Any (Larger scale)	Specified by Project Sponsor	Certificate issued to successful applicants.

Federal Regulations) under Chapter 18 of the Conservation of Power and Water Resources with various parts from 1 through 399 stipulating everything from FERC's jurisdiction to the number copies required to be filed by the applicant. Under Part 157 of the NGA a Section 7(c) applicant may seek authorization to construct interstate pipelines, expand capacity or add delivery points to a system. The application is multifaceted and comprised of many components; in this document the F-exhibit is the environmental portion of the application that consists of 12 individual resources reports. These resource reports each individually assess project impacts on "classic" environmental concerns, such as wetlands, waterbodies, fisheries and wildlife, but also provide assessments of rather "neoclassic" environmental concerns, which include topics such as socio economics and land use. Not only must the applicant provide a concise project analysis for each of the twelve topics, these resource reports must also meet minimum content standards and conform to style and formatting conditions specified by code (18 CFR 380.12); conditions that include table of contents and document formats as well as mile posting of pipeline projects. Through these reports, the applicant defines the area of potential impact; everything from access roads, pipe storage yards and extra workspace at feature crossings is identified for analysis with respect to environmental impacts arising from the proposed project.

Furthermore, projects of this nature are subject to the FERC's discretion regarding National Environmental Policy Act (NEPA) review and analysis. Larger scale efforts or those with the potential to impact sensitive environmental features will likely be required to complete an Environmental Impact Statement as apposed to Environmental Assessment, or Categorical Exclusion for projects of diminishing scale and complexity respectively. Supporting documents must also conform to the conditions stipulated by the code. FERC delegates *federal* authority to applicants to conduct informal inter agency consultations necessary to demonstrate compliance with such legislated acts as National Historic Preservation Act and Endangered Species Act. Traditionally this will involve surveys (biological and cultural) and mitigation planning.

Provided an applicant successfully negotiates the application process and receives a *Notice to Proceed* construction, activities must continue to conform with the remaining conditions stipulated by FERC. For example, stream crossing techniques (e.g., open trench, dam and pump, flume or horizontal direction drill) are specified by FERC (see FERC *Wetland and Waterbody Crossing Procedures* and also FERC *Upland Erosion Control Plan*) based upon size (width of stream) and

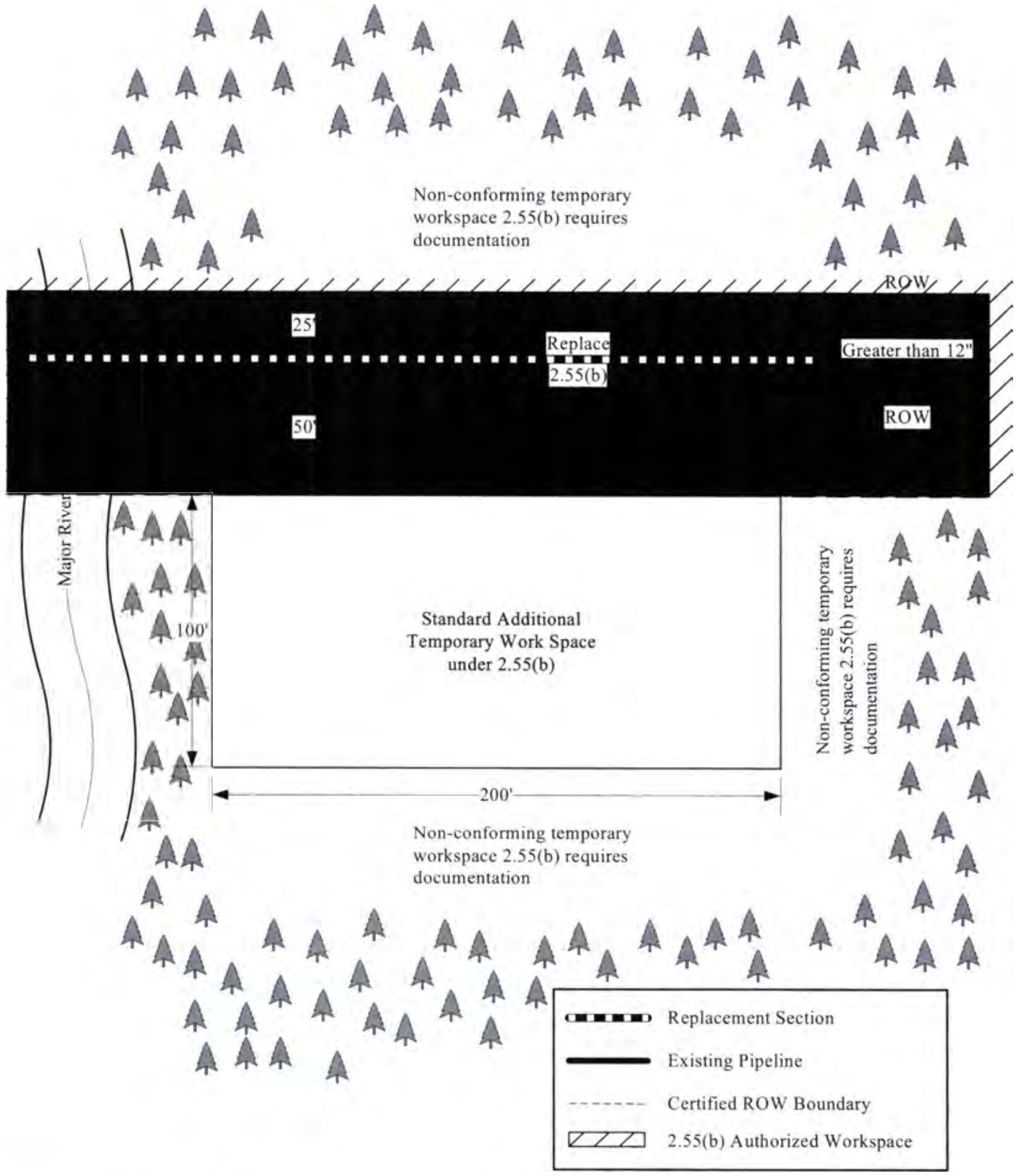

Fig. 5. Non-conforming workspace that was utilized for original installation of pipeline can be utilized again as workspace during CFR 18 Part 2.55(b) replacements provided appropriate documentation can be produced.

fishery type (e.g., warm, cool or cold water). Additionally, crossings must be completed within 24 hours and as one single continuous effort. Compliance with environmental conditions, such as the stream crossing example above may be monitored by on-site FERC construction monitors. Standard certificate conditions reach beyond the application requirements and acceptable construction techniques to also define reporting requirements that range in frequency from once per week, during construction, to quarterly during the post-construction restoration monitoring phase.

Prior notice and automatic authorizations

Limited system modifications to eligible facilities may be completed under the provisions of the *Blanket Certificate* (18 CFR 157(F)). Activities such as minor piping modifications and delivery point construction can qualify for automatic authorization; as such the project sponsor must report these projects in their *annual report* to FERC. The contents of the report include environmental documents that both define the area of potential effect and demonstrates compliance with the conditions of the blanket certificate, but unique to the automatic authorization are filed with FERC after the fact. In contrast activities completed as a *Prior Notice* filing under the blanket certificate, must provide documentation of environmental compliance (e.g., consultations, approvals and permits) prior to receiving authorization to initiate activities. The project is posted for 45 days to allow interested parties an opportunity to comment on the proposed activity. In this process, those projects that complete the posting period without challenge are authorized to proceed while those that are challenged are processed under the provisions of 7(c) application guidelines. Challenges that cannot be resolved through consultations and mitigation will be scheduled for hearing leading to decision to proceed as planned, authorization to proceed with modifications or project termination.

In clear contrast to the non-FERC jurisdictional activities described earlier, such as a large scale DOT integrity management project that may involve miles of pipeline inspection and repair that may be relatively unregulated, a small meter station project (delivery point) seeking authorization under the provisions of a *Prior Notice* may ultimately be processed as a 7(c) application and require a formal FERC hearing, if an interested party files a challenge that cannot be resolved through consultation.

REFERENCES

Code of Federal Regulations Title 18 Conservation of power and water resources Parts 2, 157 and 380. April 1, 2003. Office of the Federal Register National Archives and Records Administration. District of Columbia, Washington.

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Management of Cumulative Impacts in Transmission Line Siting

Darryl Shoemaker

Siting of a high voltage transmission line is a daunting undertaking for most utilities. Regulations, the public, and the practical realities of resource losses demand that better attempts be made to appropriately consider cumulative impacts from transmission projects. Proper stewardship, however, also demands that any analysis be relevant and effectively consider only cumulative issues of consequence and at the appropriate management level. This review provides a survey of transmission projects in the United States and Canada to determine how cumulative impacts have been considered. In particular, the survey identifies cumulative impact issues unique to linear transmission corridors, explains how they have been typically addressed, details lessons learned, and determine what aspects remain the most uncertain and problematic. A conclusion of this analysis is that a more relevant consideration of cumulative impacts is possible by focusing on related linear connected actions, point sources with direct impacts on a common valued resource, use of methodologies that utilize planning principles for valuation of impacts to select resources, and identifying other point sources more appropriately reviewed under local or regional planning regimes.

Keywords: Transmission, environmental review, cumulative impacts, siting, linear corridors, ROW

INTRODUCTION

Siting of a high voltage transmission line is a daunting undertaking for most utilities. Consideration of cumulative impacts is not a subject that utilities usually are interested in loading on to an already difficult review process. The most common reason for this aversion relates to the relative difficulty in setting study parameters and finding appropriate methods for analysis that results in a meaningful assessment and therefore does not lead to significant delays. In addition, lengthy linear projects like transmission lines pose unique challenges for consideration of cumulative impacts, and most literature on cumulative impacts has limited its analysis to point sources.

This review provides a survey of transmission projects in the United States and Canada to determine how cumulative impacts have been considered. In particular, the survey identifies cumulative impact issues unique to linear transmission corridors, explains how they have been typically addressed, details lessons learned, and determine what aspects remain the most uncertain and problematic. A conclusion of this analysis is that a more relevant consideration of cumulative impacts is possible by focusing on related linear connected actions, point sources with direct impacts on a common valued resource, use of methodologies that utilize planning principles for valuation of impacts to select resources, and identifying other point sources more appropriately reviewed under local or regional planning regimes.

WHAT ARE CUMULATIVE IMPACTS?

One of the first challenges is establishing agreed upon definitions. The U.S. Council on Environmental Quality (CEQ), which has provided environmental review guidelines used by federal and state agencies, states that "cumulative impacts" result from:

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> The incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

Several U.S. agencies, such as the U.S. Army Corps of Engineers (USACE) and Federal Energy Regulatory Commission (FERC), have provided some limited interpretation of this definition, but for the most part they have referred to the CEQ definition and an associated guidance document (CEQ, 1997). While many agencies have not defined cumulative impacts, they have stated the importance of their consideration.

The United States courts have also provided some direction. In particular, over 40 court cases have involved cumulative impacts, and many of them hinged on the determination of what activities should be considered "reasonably foreseeable future actions" (Canter and Rumrill, 1997).

The Canadian Environmental Assessment Act (CEAA) requires consideration of "cumulative effects," but does not provide a definition. Shoemaker (1995), after reviewing the CEAA, associated guidance documents (Canadian Environmental Assessment Research Council [CEARC], 1986) and related literature, offered the following definition:

> A change in the environment resulting from multiple initiatives of the past, present and reasonably foreseeable future, which combine in an additive, amplifying, or discontinuous manner. Key instances occur when such interactions threaten or induce impairment or loss of valued environmental components.

Guidance for the CEAA (Hegmann et al., 1999) does discuss what future actions should be included by indicating that only those projects and activities that are relevant to the proposed project and "on the books" must be assessed. The guidance notes three categories of activities: certain actions, reasonably foreseeable actions, and hypothetical actions.

A clear understanding of what cumulative impacts (effects) are must be articulated in an environmental review if it is to meet the intended objectives of its statute or, more importantly, the expectations of the participating public. Indeed, the significance of cumulative impacts depends in large part on the value placed on those resources that may be affected. "The ultimate significance and meaning of cumulative impacts rests against some 'ideal' environment or state, which is being disturbed by the collective effects of a given project. The judgment of whether impacts are significant requires a look beyond both the spatial limits of a given area and the narrow goals of a piecemeal or individual action" (Horak et al., 1983).

TRANSMISSION PROJECTS POSE UNIQUE CHALLENGES FOR CONSIDERATION OF CUMULATIVE IMPACTS

Site-specific project development has wrestled with how best to address cumulative impacts. Two questions or dilemmas in particular stand out in all discussions concerning cumulative impacts. First, how to set reasonable boundaries? Second, what methods to use in assessing impacts. Transmission projects literally stretch these two challenges out.

Difficulties in setting boundaries

There is general agreement on the need for expanded spatial and temporal boundaries when considering cumulative impacts. This is because the development boundary for the project (stressor) may be markedly different than the boundary of its effects in concert with other past, present or reasonably foreseeable projects. This was highlighted in one court case involving a proposed road (Northwest Indian Cemetery Protective Association. v. Peterson, 1985), where it was determined that projects were linked not only by geographic area, but also by threats to common resources.

This court case illustrates the challenge faced in setting boundaries for linear projects, considering the potential number of other projects along the corridor and the variety of common resources that may link them together (e.g. ecological, social, economic). As a result, boundaries for analysis vary almost as greatly as the work of the authors themselves. Common spatial boundaries suggested include watersheds and other ecologically defined units (e.g. recreational features or threatened and endangered [T&E] species habitats). Most environmental review documents typically consider only one or two valued environmental components, whereas a linear project may impact numerous components. As a result, the boundaries will be determined mainly on a case-specific basis, and several boundaries may apply in one assessment.

Limited methodologies

Despite the recent surge in interest on cumulative impacts, as demonstrated in the literature (Antoniuk, 2002; Finley and Revel, 2002) and dedication of conference sessions (International Association for Impact Assessment 2003 and 2004), the potential for matching current understanding to regulatory needs remains elusive. The proper scope of cumulative impacts analysis remains a mystery to many resource managers. This is no more apparent than in the area of agreed upon methodologies. Antoniuk (2002) notes that uncertainty concerning methods is driven by a variety of technical issues:

> Lack of detailed monitoring information on past development activities and key environmental parameters; absence of defined resource use or ecological thresholds; availability of credible and

defensible information on present and future development activities; and difficulty in predicting synergistic, discontinuous or unanticipated resource and system effects (CEARC, 1986; Sonntag et al., 1987).

This results in a situation where agencies specifically require consideration of cumulative impacts but rarely provide corresponding methods for analysis. A good example is the Montana Transmission Siting process (Montana State Standards, 2002), which sets criteria for approval that includes consideration of cumulative impacts, but provides no guidance.

Recently, a mix of appropriate approaches and methods (e.g., matrices, checklists, indicators), depending on the issues and objectives, has been suggested in federal guidance documents (CEQ, 1997; Hegmann et al., 1999). Use of these approaches and methods is dependent upon the project and issues at hand. These methodologies, however, are for the most part based on, and applicable to, projects that are isolated in space rather than large corridor projects (Antoniuk, 2002), and are therefore based on and limited by the resulting boundaries chosen.

Fragmented jurisdictional review

The development of cumulative impacts guidance must be accompanied by a capacity to implement by the responsible governing authority. One of the key challenges that beset public administrators are the large and complex jurisdictional systems, characterized by divided and overlapping functions carried out at multiple levels (Bartlett and Baber, 1989). Added to this bureaucratic reality is the fact that it overlies an even more complex ecological fabric and the associated competing natural resource demands. In all of this, coordination is crucial to any measure of success. Large transmission projects by their nature involve a large number of jurisdictions, making successful assessment of cumulative impacts a particularly difficult coordination challenge.

An excellent example involves the Arizona Corporation Commission, which is charged with the review and approval of new power generation facilities. The Commission was deluged with applications between 1999 and 2002, during the recent boom in gas-fired electric generation projects and associated transmission facilities. Environmental planners from the Commission concluded that:

> There are a range of difficulties and contradictions associated with responding to the effects of deregulation in Arizona, particularly because of the separation of generation and transmission components of the electrical system and institutional deficiencies in addressing cumulative effects. Interstate transmission lines constitute another source of contradiction or conflict, largely as a result of the difficulties in coordinating state regulations, and negative public perceptions in Arizona about experiencing local impacts to service 'foreign' demand centers such as California and Nevada" (Donahue et al., 2001).

Counterbalancing this has been the coordinating influence of federal NEPA policy, which has required agencies and proponents to engage in greater sharing of scientific and technical information to substantiate their positions (Bartlett and Baber, 1989). Creating a defensible and hence increasingly environmentally sound proposal in a timely manner has led to increased joint planning.

Increasing legal attention

The purpose of an environmental review document is to provide substantially complete information for decision makers to make informed decisions concerning a proposed project. Many successful challenges to projects have hinged on the ability to demonstrate that decision makers did not have all the necessary information. Cumulative impacts stand out as a common gap in environmental documents that have been used to make this argument (Canter and Rumrill, 1997).

> The courts have been increasingly willing to scrutinize the analysis of the effects of the agency action, combined with other relevant actions, and reject NEPA [National Environmental Policy Act] documents because of inadequate cumulative impact analyses (Herson and Bogdan, 1991).

This observation remains true, as illustrated by subjects covered in rights-of-way symposiums. A review of papers presented in the Environmental Concerns in Rights-of-Way Management symposiums, which have met since 1976, is very instructive. It was not until 2000 that the subject of cumulative impacts was discussed in detail. This is coupled with the fact that project opponents are increasingly aware that cumulative impacts can be used as the centerpiece of a serious challenge, and they effectively use the Internet to exchange this information. One example was the legal challenge to a presidential permit for a proposed power line from Mexico to Southern California. In May 2003, a federal judge denied the permits, claiming that several issues had not received proper review, including cumulative impacts:

> The court finds that cumulative impact analysis in the [environmental assessment] is inadequate because the analysis fails to consider the combined impacts of future, specific power plants in the region and the cumulative impact on water resources (Electric Transmission Week, 2003).

TYPICAL CUMULATIVE ASSESSMENT APPROACHES IN LINEAR PROJECTS

A number of approaches and concepts have developed specific to the unique challenges facing the understanding of cumulative impacts related to linear projects like transmission lines. Although the case studies reviewed differ greatly in geographic location, they do appear to share common approaches to cumulative impacts assessment. This section attempts to categorize these common elements.

Use of regional planning

Hubbard (1989) and Smit and Spaling (1993) have noted the tendency among researchers to try and separate their work on cumulative impacts into strictly scientific or planning realms. Developers often favor strictly quantitative analysis, which avoids questions of value (Canadian Electrical Association, 1992; Roots 1983). The distinction between the two approaches is one of emphasis. "The scientific emphasis is on the analysis of cumulative effects, whereas the planners come at the problem from a normative policy perspective" (Spaling and Smit, 1993). In other words, the latter utilizes planning principles to establish priorities between resource allocation choices. In the face of uncertain interactions and a lack of good data, reviewers will tend toward the latter approach, which is a valid means for managing issues, if an effective public consultation process is used to help establish priorities. Planning principles, however, are often associated with regional resource management or Comprehensive Plans. These plans typically are developed over a long time period, involve numerous stakeholders, take into account a large geographic area (e.g. watershed or national forest), forecast future uses, and are meant to satisfy specific regulatory directives given to the lead agency responsible for the plan.

Two challenges can occur for a project proponent related to regional resource management plans: the project impacts a regional plan that has not taken into account a linear project of the type proposed (e.g. electric or gas transmission line); or, more likely, it is located in an area with no regional planning in place. In either case, the proponent is often pressured to postpone the project until the plan can be updated or asked to take on a large role in updating the plan. These requests normally go beyond the project-specific requirements of an environmental review and pose unreasonable burdens on the proponent. This is often due to the fact that by definition regional planning includes a broader public mandate. While regional planning that accounts for cumulative effects (CE) needs to occur, project proponents should only be tasked with analysis of cumulative effects as relates to their project. Antoniuk (2002) takes a similar approach:

> While completion of a project-specific CEA [cumulative environmental assessment] may be viewed as a less desirable alternative by some, it ensures that regulatory requirements are met and provides regulators and stakeholders with information on potential cumulative effects that warrant mitigation and management.

American Electric Power (AEP) faced this challenge in proposing a 765-kV transmission line from West Virginia to Virginia that would cross the Jefferson National Forest, which resulted in the need for an environmental impact statement (EIS). In addressing cumulative impacts to Jefferson National Forest, AEP stated, "Cumulative impacts to a variety of resources will be assessed in the EIS. Many of these will be associated with the right-of-way for the proposed transmission line, however, it is our belief that the Jefferson National Forest Land and the Resource Management Plan would be the appropriate place to analyze and assess the cumulative effects, on a Forest wide basis, of linear land uses (rights-of-way)" (U.S. Forest Service, 2002).

California legislators recognized that this burden can be unreasonable and therefore developed an option for proponents undergoing review under the California Environmental Quality Act (CEQA) (California Energy Commission Guidelines, 2002):

> CEQA mandates two ways in which cumulative impacts may be evaluated. One of these mandated approaches is to summarize growth projections in an adopted general plan or in a prior certified environmental document. The second method involves compilation of a list of past, present, and probable future projects producing related or cumulative impacts [Guidelines, Section 15130 (b)1(A)].

This guidance in effect gives the proponent the option to rely on existing growth projections. If these appear inaccurate, the proponent can evaluate past and proposed projects using a cumulative impacts definition similar to that contained in the federal environmental review guidance.

If the proponent chooses to compile a listing of past and proposed projects, then there is the question as to how to summarize prior studies. Some direction is provided by a court case involving a potential road (Coalition on Sensible Transportation v. Dole, 1987), where the court concluded that it "makes sense to consider ... cumulative effects by incorporating the effects of other projects into the background database of the project at issue, rather than restating the results of prior studies," and "EA [environmental assessment] and FONSI [finding of no significant impact] are sufficient to alert interested members of the public to any arguable cumulative impacts."

Determination of what to include

A second range of issues revolves around what projects fall within the basket of past, present and reasonably foreseeable projects to include in a review. Two possible sieves have been used to make this determination: project definition and affected environment.

Project definition
Regulatory guidance and legal cases have provided direction as to what kind of projects should be included in a study. This direction includes projects that are not speculative, constitute an independent utility or function, information about a future stage is meaningfully possible, and likely will be needed in a common corridor.

Affected environment
The second sieve resulting from regulatory guidance and legal cases deals with the affected resources. This approach includes identification of valued environmental components (e.g., Threatened and Endangered (T&E) habitats, historic districts, parks and planning districts) as the basis for scoping the impacts analysis, geographic or resource pathways by which a contaminant or adverse effect is transmitted (e.g., watershed), and consideration of the design life.

Analysis
As noted earlier, when speaking to challenges related to cumulative impacts, there were a very limited number of authors who suggested specific methods outside of the federal guidance documents (CEQ, 1997; Hegmann et al., 1999).

One option discussed is to use a matrix approach for analysis of data (CEQ, 1997). Another option is to use planning principles and rely on use of valued environmental components. The Indicator Approach (Shoemaker, 1995) follows this tact, as does guidance subsequently developed for the CEAA (Hegmann et al., 1999). The Indicator Approach focuses on those indicators in the natural, social and economic environment that could be used to assess cumulative impacts. Indicators are defined as "a character of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure" (Environment Canada, 1992). The emphasis is placed on the review process rather than an analytical method, and on values and goals rather than quantitative standards. This does diminish the need for a strong scientific component; rather, it simply recognizes limitations in the present cumulative impacts management context.

Mitigation
Mitigation measures were noted in very few papers or regulations. The State of Oregon (Oregon State Standards, 2002) has established standards for siting wind energy facilities, which include consideration for cumulative impacts from associated transmission lines. In particular, the Standards (345-024-0015) suggest co-location with existing transmission lines and minimizing the artificial habitat for raptors or raptor prey (e.g. horizontal perching points on the tower where electrocution may occur). Co-location in general may serve to mitigate impacts in specific instances. It may, however, have the opposite effect when the number of co-located utilities reaches a point where they exceed the given capacity of the corridor and unduly impact underlying landowners (Jenkins, 2002; Nixon et al., 2002).

ScottishPower (Marshall, 2001) has established a framework for identifying preferred mitigation related to the construction of electric transmission lines to avoid unacceptable impacts. They have developed a seven–step test to screen "useful" mitigation measures, as follows:
- Specific to the predicted effect;
- Feasible;
- Significance of impact requiring mitigation;
- Effective;
- Proposal conformity;
- Verifiable of approach; and
- Enforceability.

Marshall (2001) notes that these tests are intended for use in a hierarchical approach, but practically used in a case-by-case basis. In other words, whether a measure is specific to the potential impact and can be feasibly implemented will filter mitigation options. Whether a measure reduces an impact to less than significant, has been demonstrated effective, has buy in from all stakeholders, and can be verified and enforced will filter the preferred mitigation option. Marshall argues that use of these principles, can strengthen environmental reviews into concise, defendable but environmentally sympathetic proposals.

LESSONS LEARNED

Cumulative impacts have received limited attention in most environmental reviews conducted for transmission projects. Many of the instances where an approach for consideration of cumulative impacts was developed were related to pipeline projects, and, to a lesser extent, railway consolidations (e.g. Conrail). From this pool of assessments, the environmental review managers cited a number of "lessons learned."

Antoniuk (2002), after involvement in the review of a 1559-km gas pipeline (Alliance), suggested a streamlined approach for consideration of cumulative impacts. He argued that significant impacts from gas pipelines were relatively well understood. Therefore, Antoniuk suggested using an approach similar to the Indicator Approach, for evaluating impacts only in "Representative Areas." Selecting a Representative Area, Antoniuk argues, will avoid missing cumulative impacts in an analysis at a larger scale. This line of thought is similar to the discussion of sub-boundaries for valued environmental components. In his paper, Antoniuk suggests a number of criteria for selecting Representative Areas, as follows:
- Size and nature of the linear corridor and potential project effects;

- Nature and location of past and future projects and activities;
- Availability and utility of existing data and knowledge;
- Inclusion of both common and uncommon biophysical conditions (i.e. vegetation, habitat or species);
- Reflection of relevant ecological boundaries; and
- Reflection of administrative boundaries.

Another lesson derived from similar pipeline projects concerns co-location. Co-location frequently is cited, as discussed above, as a guiding principle for siting of linear projects to mitigate cumulative impacts. Jenkins (2002) and Nixon et al. (2002), however, both note that co-location can also raise the potential for adverse effects. In particular, they cite undue burdens on landowners and potential safety concerns. For the landowners, the total area of right-of-way likely will increase, as will associated restrictions, especially if the linear facilities differ in nature (e.g. electric versus gas transmission). Regarding safety, examples exist of damage and facility outages during construction of co-located facilities or induction issues from a power line to a pipeline or railroad facility. In addition, in an age of heightened security concerns, regulatory agencies may desire separation of key facilities to prevent outages from multiple facilities at the same time.

One final example relates to the Western Governors' Association, which signed a protocol for siting and permitting of interstate electric transmission lines in 2002 in conjunction with the departments of Interior, Agriculture and Energy, as well as the CEQ. "The purpose of the Protocol is to establish a framework that will enable affected states, local governments, federal agencies and tribal governments to participate in a systematic, coordinated, joint review process for siting and permitting of interstate transmission lines in the Western Interconnection" (Western Governors' Association, 2001). They believe this process will increase efficiency, reduce duplication, and reduce the timeline of the siting process. This effort appears to directly address the barrier of fragmented jurisdiction issues and, when linked with a regional transmission planning process, should better address need and alternative review components of environmental reviews.

The Western Governors' Association initiative is also in line with a similar effort at the federal level. Energy bill legislation proposed in 2003 included a measure that would allow for states to "enter into interstate compacts establishing regional transmission siting agencies to facilitate coordination among the states within such areas for the purposes of siting future electric energy transmission facilities and to carry out state electric energy transmission siting responsibilities" (December 2003 draft of Conference Committee Energy Bill). In this approach, states agree to a joint study of a transmission project but retain their individual authority to approve or reject the project. This approach would greatly streamline interstate transmission lines. The key, however, would be the states' ability to clearly define roles and responsibilities in advance of a proposed project for the stated benefits to be realized.

LOOKING AHEAD

Cumulative impacts analysis requires syncretic thinking, which seeks a whole that may be significantly different than the summation of the parts (Caldwell, 1989). Caldwell insightfully recognized the value of considering cumulative impacts. It is not to delve into more arcane levels of interesting detail, but rather to understand impacts in a way that cannot be grasped through cause and effects analysis. It also uses the word "seeks," however, which recognizes that the ability to grasp the whole is severely limited by the uncertainty inherent in any system. Coupled with this uncertainty is the recognition that inherent in any framework or technique for consideration of cumulative impacts is fiscal and time restraints.

While the challenges to consideration of cumulative impacts for linear projects appear daunting, the literature surveyed provides many examples of creative and efficient reviews that have resulted in better projects. In short, cumulative impacts can better be considered by:

- Including related linear projects that overlap with the project under review (i.e. "connected actions");
- Focusing on point sources with direct impacts on a common valued resource;
- Filtering out unconnected point or linear sources that are more appropriately reviewed under local or regional planning regimes; and
- Utilizing methodologies that utilize planning principles for valuation of impacts to select resources.

Concerning the last point, planning approaches to cumulative impacts should not only provide strategic direction but also consider incentives that offer a net gain on planning and assessment investments (Shoemaker, 1995). In other words, it is not enough to identify resources that the community values if you have no ability to protect or enhance those resources, which is an increasing reality in the face of governmental budget cuts. Communities can go beyond playing development defense and hoping simply for a no net loss of valued resources. Instead they can use development to restore presently degraded resources whether it is a historic building, a roadway improvement, a native prairie or a cold water fishery.

In summary, regulations, the public and the practical realities of resource losses demand that better attempts be made to appropriately consider cumulative impacts from transmission projects. Proper stewardship, however, also demands that any analysis be relevant and effectively consider only cumulative issues of consequence and at the appropriate management level.

REFERENCES

Antoniuk, T. 2002. "Cumulative Effects Assessment and Linear Corridors: The Representative Areas Approach," in J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds.), Environmental Concerns in Rights-of-Way Management: Seventh International Symposium, Oxford: Elsevier Science Ltd.: 209–218.

Bartlett R.V. and W.F. Baber. 1989. "Bureaucracy or Analysis: Implications of Impact Assessment for Public Administration. in Bartlett R.V. (ed.), Policy Through Impact Assessment, New York: Greenwood Press: 143–154.

Beanlands, G.E. and P.N. Duinker. 1983. An Ecological Framework for Environmental Impact Assessment in Canada, Hull: Institute for Resource and Environmental Studies, Dalhousie University and the Federal Environmental Assessment and Review Office.

Caldwell, L.K. 1989. "Understanding Impact Analysis," in Bartlett, R.V. (ed.), Policy Through Impact Assessment, New York: Greenwood Press: 7–16.

California Energy Commission Guidelines. 2002. Section 15130 (b)1(A).

Canadian Electrical Association. 1992. "Cumulative Effects Assessment: Principles for Application for Electric Utilities in Canada," draft.

Canadian Environmental Assessment Research Council (CEARC) and the U.S. National Research Council Board on Basic Biology. 1986. Cumulative Environmental Effects: A Binational Perspective, Ottawa: CEARC.

Canter, L.W. 1999. Personal communication providing bibliography for case law on cumulative impacts.

Canter, L.W. and J.N. Rumrill. 1997. "Addressing Future Actions in Cumulative Effects Assessment," Impact Assessment and Project Appraisal, 12(4): 207–218.

Cleckley, E.W. 1992. Position Paper on Secondary and Cumulative Impacts Assessment, www.fhwa.dot.gov/environment/2_c_imp.htm: Federal Highway Administration.

Connecticut Department of Transportation. (unknown date) Route 2/2A/32 Transportation Improvement Study.

Council on Environmental Quality (CEQ). 1997. Considering Cumulative Effects Under the National Environmental Policy Act, Washington: Council of Environmental Quality, 64 pp.

Donahue, J., M. Jerome, and M. Siegel. 2001. "Environmental Regulation Versus Electric Utility Deregulation: Arizona's Power Environment in the 21st Century," www.naep.org/conference01/donahue: National Association of Environment Professionals.

Electric Transmission Week. May 12, 2003.

Environment Canada. 1992. Canada's National Indicators Project, Ottawa: Environment Canada.

Finley, C.G. and R.D. Revel. 2002. "Pipeline Projects and Cumulative Effects Assessment Issues," in J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds.), Environmental Concerns in Rights-of-Way Management: Seventh International Symposium, Oxford: Elsevier Science Ltd.: 219–231.

Hegmann, G., R. Eccles, and K. Strom. 1999. Cumulative Effects Assessment Practitioner Guide. Hull, Quebec: AXYS Environmental Consulting Ltd. and the CEA Working Group for the Canadian Environmental Assessment Agency.

Herson, A.I. and K.M. Bogdan. 1991. "Cumulative Impact Assessment under NEPA," Environmental Professional, Vol 12: 79–90.

Horak, G.C., E.C. Vlachos, and E.W. Cline. 1983. Methodological Guidance for Assessing Cumulative Impacts on Fish and Wildlife, Washington: Fish and Wildlife Service, U.S. Department of the Interior, p. 15.

Hubbard, P.M. 1989. Cumulative Effects Assessment and Regional Planning in Southern Ontario, Ottawa, ON: Canadian Environmental Assessment Research Council (CEARC).

Jenkins, D.F. 2002. "Co-Location of Linear Facilities: Realistic Opportunity or Unrealistic Expectation," in J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds.), Environmental Concerns in Rights-of-Way Management: Seventh International Symposium, Oxford: Elsevier Science Ltd.: 195–200.

Marshall, R. 2001. "Application of Mitigation and its Resolution within Environmental Impact Assessment: An Industrial Perspective," Impact Assessment and Project Appraisal, 19(3): 195–204.

Maryland State Highway Administration. 2000. Secondary and Cumulative Effects Guidelines.

Montana State Standards. 2002. 17.20.1604.

Nixon, J., A. Jalbert, K. Etherington, T. Bossenberry, and D. Clark. 2002. "Saturation Threshold in a Multi-Pipeline Corridor Expansion Project," in J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds.), Environmental Concerns in Rights-of-Way Management: Seventh International Symposium, Oxford: Elsevier Science Ltd.: 201–207.

Oregon State Standards. 2002. 345-024-0015.

Roots, E.F. 1983. "Environmental Planning for Mining of Energy Minerals." in J.D. Weibe (ed.), Final Report: International Workshop on Environmental Planning for Large Scale Development, Vancouver: Environment Canada: 55–66.

Shoemaker, D.J. 1995. Cumulative Environmental Assessment, Waterloo: University of Waterloo, Dept. of Geography. Publication Series No. 42, 129 pp.

Smit, B. and H. Spaling. 1993. "Methods for cumulative effects assessment." Environmental Impact Assessment Review, 15: 81–106.

Sonntag, N.C., et al. 1987. Cumulative Effects Assessment: A Context for Further Research and Development. Hull: Canadian Environmental Assessment Research Council and ESSA Environmental and Social Systems Analysts Ltd.

U.S. District Court. Northwest Indian Cemetery Protective Assn. v. Peterson, 565 F. Supp. 586, 594–595.

U.S. Forest Service. 2002. American Electric Power: Non-Significant Issues, Federal Agencies Analysis. www.southernregion.fs.fed.us/gwj/apco/nonsignfissues.

Western Governors' Association. 2001. Conceptual Plans for Electricity Transmission in the West. Report to the Western Governors' Association Meeting in August, 2001.

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Fast-Track Permitting: A Case Study of the Kern River 2003 Expansion Project

George Welsh, Tim Powell, Brent Arnold, Mike Donnelly and Sara McMahon

The Kern River 2003 Expansion Project was the first major natural gas project recently approved and constructed under what has become the FERC Pre-Filing Process. The project involved looping approximately 720 miles of existing pipeline in Wyoming, Utah, Nevada and California, and construction of 3 new and modifications to 6 existing compressor stations. Given the energy demand situation in California, and commitments to shippers to be in-service in May 2003, it was necessary to expedite other permitting as well, compared to a traditional approach, while complying with existing regulations. Preparation of the FERC application began in February of 2001, a complete application was filed on August 1, 2001, the Certificate received in July 2002, and notices to proceed by spread were received beginning in August 2002 to allow construction to meet the in-service date. A number of key activities were moved into the pre-filing and pre-certificate phases, notably selection of a third-party EIS contractor and initiation of interagency scoping before the August 2001 filing, submittal of draft resource reports for FERC staff review in advance, an aggressive field survey program, and early issues resolution or mitigation plan completion. This approach allowed preparation of the post-certificate implementation plans to be underway before the final EIS and certificate were issued. Other permits and approvals followed parallel schedules. Clearly defining the project scope, consulting early and often with federal and state reviewers and other stakeholders, as well as developing supporting information and plans needed early in the filing process significantly expedited the 2003 Expansion Project.

Keywords: Kern River, Federal Energy Regulatory Commission (FERC), Bureau of Land Management (BLM), stakeholders, scoping, Environmental Impact Statement (EIS), certification, grant of right-of-way, permitting, implementation plans, ROW

INTRODUCTION

The Kern River 2003 Expansion Project was the first major natural gas project recently approved and constructed under a more fast-track or expedited Federal Energy Regulatory Commission (FERC) 7(c) certification and permitting process. Given critical energy demands during the winter of 2000/2001, firm shipper agreements required delivery of new natural gas supplies by May 2003. In order to reduce the time required for the certification proceedings once the 7(c) Application was formally filed and facilitate the expedited approval of the Project to meet commitments to its shippers, Kern River Gas Transmission Company (Kern River) accelerated pre-filing consultation with the FERC and other key federal and state agencies on issues, surveys, interagency scoping and development of the Environmental Report (ER) and other exhibits in early 2001 in an advance of the actual FERC filing. In general, this fast-track process is similar in many respects to the FERC's voluntary or optional Pre-Filing Process currently in use on a number of natural gas transmission as well as Liquefied Natural Gas projects. Formal guidance and interagency cooperative agreements for the Pre-Filing Process have since been developed by the FERC and cooperating agencies (FERC, 2002a; 2002b). The terms *"expedited"* or *"fast-track"* approach used in this paper are therefore in the context of the relatively unique requirements for the Kern River 2003 Expansion Project, rather than a project certificated and constructed under the cur-

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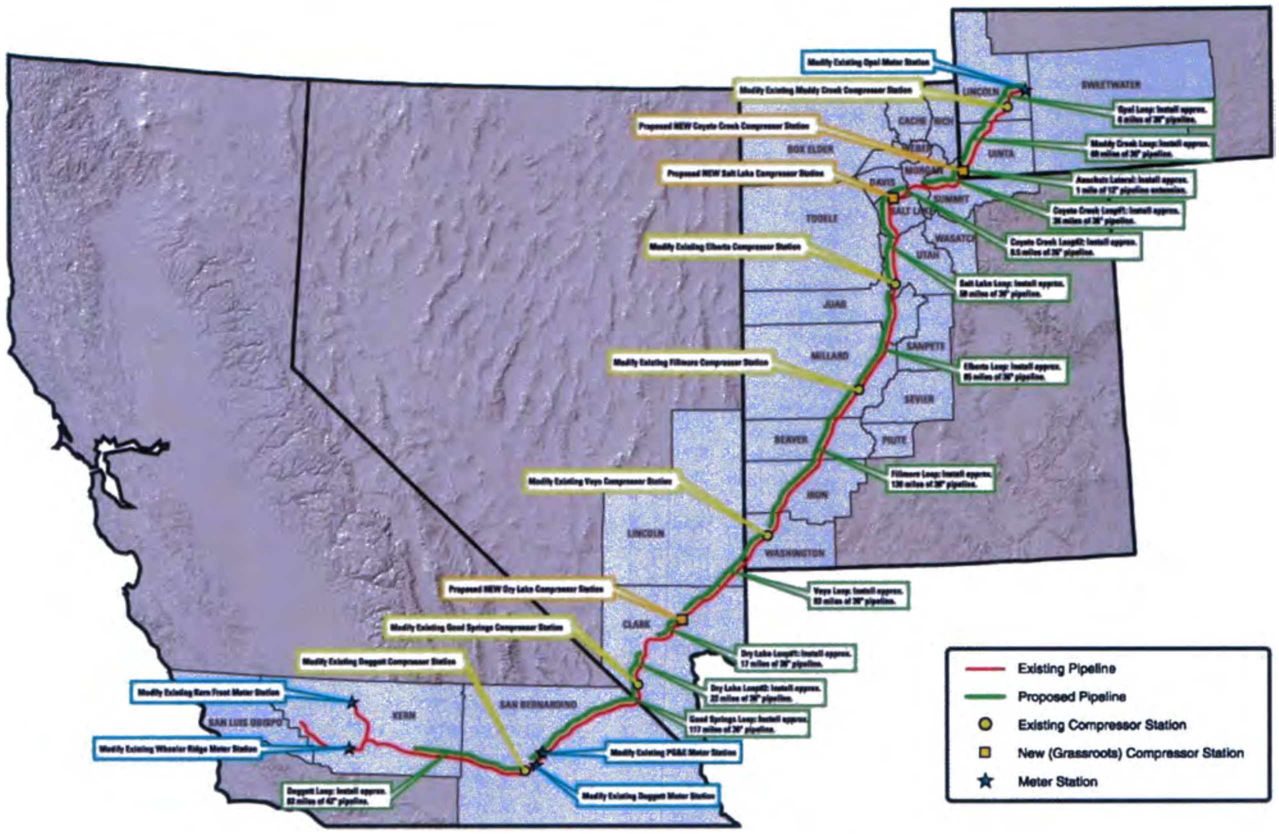

Fig. 1. Location of Kern River 2003 expansion project facilities.

rent FERC Pre-Filing Process. For use on other existing and future projects, *"pre-filing"* is the proper terminology.

In addition to conducting pre-filing consultation with agencies to facilitate the FERC 7(c) Application, Kern River also employed fast-track measures to expedite obtaining notices to proceed (NTPs) for construction from the FERC and other agency approvals. Kern River intensified effort to obtain the following approvals on a much reduced time-frame: the Certificate of Public Convenience and Necessity (Certificate) from the FERC, amendments to the original Grant of Right-of-Way from the Bureau of Land Management, the California Environmental Quality Act (CEQA) determination for construction and operations for the facilities located in the State of California from the California State Lands Commission (CSLC), as well as permits from the U.S. Corps of Engineers (USACE) and concurrence from the U.S. Fish and Wildlife Service (USFWS).

While the applications and experiences presented herein are based on the Kern River 2003 Expansion Project, they nonetheless have similar applications for the FERC Pre-Filing Process as well as future projects where it is necessary to expedite schedules where possible while complying with all applicable federal, state, and local environmental laws and regulations.

PROJECT DESCRIPTION

Kern River completed the expansion of its interstate natural gas pipeline system in May of 2003, which provided for the delivery of an additional 902,626 dekatherms per day (Dth/d), or 885.6 million cubic feet per day (Mmcfd) of natural gas transportation capacity to some 18 shippers in the states of Utah, Nevada, and California. The expansion, known as the Kern River 2003 Expansion Project (the Project), extends from southwestern Wyoming to southern California, doubling the capacity of the original Kern River system constructed in 1991. The expansion involved the construction of approximately 720 miles of 36 and 42-inch diameter pipeline loops along the existing mainline, including 69.3 miles in Wyoming; 341.4 miles in Utah; 120.6 miles in Nevada; 104.0 miles on the Mainline in California; 82.2 miles on the Mojave Common System (California); and an 0.8-mile, 12-inch diameter pipeline lateral extension in Uinta County, Wyoming. The Project also included construction of three new compressor stations in Wyoming, Utah and Nevada; modifications to six existing compressor stations in all four states, which added a total of 163,700 horsepower; modifications to meter stations in Wyoming and California; 24 pig launcher/receiver facilities; and 55 mainline valves and associated facilities (Fig. 1).

Except where required by topography, land use, presence of other utilities, or other constraints, the pipeline loops were laid at a typical 25-foot offset from the existing pipe centerline utilizing a 75 to 90-foot construction right-of-way (ROW) with additional temporary work space (ATWS) where required for road and railway crossings, streams and washes, side hills, and other land use or engineering constraints. To further minimize impacts, launcher/receiver facilities were constructed within the fence lines of or adjacent to other aboveground facilities to the extent feasible. Construction activity was restricted to the approved corridor environmentally inventoried and surveyed during 2001 and 2002. Where additional space or changes were required and justified for ATWS or for modifications to existing access roads, surveys were conducted immediately prior to construction in 2002 by biological monitors and cultural resource specialists, and accepted as variances by regulatory agencies.

REGULATORY CONTEXT

Overall, the Kern River 2003 Expansion Project was under the jurisdiction of and certificated by the FERC under Section 7(c) of the U.S. Natural Gas Act of 1938. As lead federal agency, the FERC also was responsible for National Environmental Policy Act (NEPA) review and compliance. In addition, about 50 percent of the lands crossed were federal lands predominantly administered by the U.S. Department of the Interior, Bureau of Land Management (BLM). Federal lands also included a crossing of the Dixie National Forest in Utah, and Humboldt-Toiyabe National Forest/Spring Mountain National Recreation Area in Nevada administered by the U.S. Department of Agriculture, Forest Service (USFS). The loops also crossed portions of five military bases including: Camp Williams in Utah; Nellis Air Force Base in Nevada; and, Fort Irwin, Marine Corps Firing Range and Edwards Air Force Base in California. The BLM was lead federal agency for amending the Grant of Right-of-Way under Section 28 of the Mineral Leasing Act. In addition, the BLM and USFS were cooperating agencies with the FERC under NEPA, with collective NEPA review responsibility for all federal lands. As such, the BLM coordinated with other federal land management agencies.

In addition, the State of California had comprehensive review under its California Environmental Quality Act (CEQA) and became a cooperative agency with the FERC for the Environmental Impact Statement/Environmental Impact Report (EIS/EIR), which was subsequently issued as final in June 2002 (FERC et al., 2002c). It has been the practice in the U.S. in more recent years for the federal and State of California's respective EIS and EIR processes to be combined in one document, rather than independently preparing separate documents under schedules which could differ. However, each must satisfy its federal and state implementing regulations and practices in this cooperative effort.

There were also a number of other federal, state and local permits and approvals needed, not unlike other comparable projects of such size in this region of the U.S. Permits and approvals that became critical paths to the schedule are further addressed herein.

SCHEDULE DEMANDS REQUIRING A FAST-TRACK APPROACH

The Kern River 2003 Expansion encountered unique scheduling needs that required evaluating ways to expedite the schedule. In the winter of 2000/2001, the State of California experienced high energy shortages and curtailment of power service. The reports of rolling blackouts for example were commonly reported in the national media. Moreover, 6,000 Megawatts (MW) of new power generation was forecasted in Nevada and California, with natural gas being the fuel of choice. Because of this critical demand, firm shipper responses to Kern River's Open Season in late 2000 and 2001 required this new service be established by May 2003, with significant liabilities for both Kern River and its shippers if the additional volumes of natural gas were not available for electrical generation and related uses for the 2003 cooling season and peaks of high power demand. Thus, the time available for the completion of a gas flow analysis, surveys, design land acquisition, certification and permitting, and receiving NTPs for construction became compressed into a period of 18 months.

It became obvious that the traditional FERC certification process and completion of the EIS/EIR and post-certificate implementation plans precluded going into construction in the summer of 2002 to be in operations by May 2003. The EIS itself was the critical environmental path notwithstanding the FERC's responsibilities in the realm of non-environmental issues. In addition, the CEQA review and preparation of an EIR tended to add more uncertainty, in that the schedule to complete an EIR and issue the CEQA determination are generally acknowledged to be more variable or subject to greater risk than the time frames required for FERC review on projects where only an EIS is required.

Given that the traditional schedule would have prevented Kern River's going to construction in time for a May 2003 inservice date, Kern River consulted with the FERC, BLM, and other agencies on ways to expedite the schedule for completion of the EIS/EIR, while allowing them to meet their regulatory responsibilities under NEPA, as well as in the case of California providing for CEQA compliance. Figure 2 provides a comparison of the traditional schedule, as compared with the actual schedule realized on the Kern River 2003 Expansion. It is important to note that the time frame to complete the post-certificate implementation plans required for issuance of the NTPs can be highly

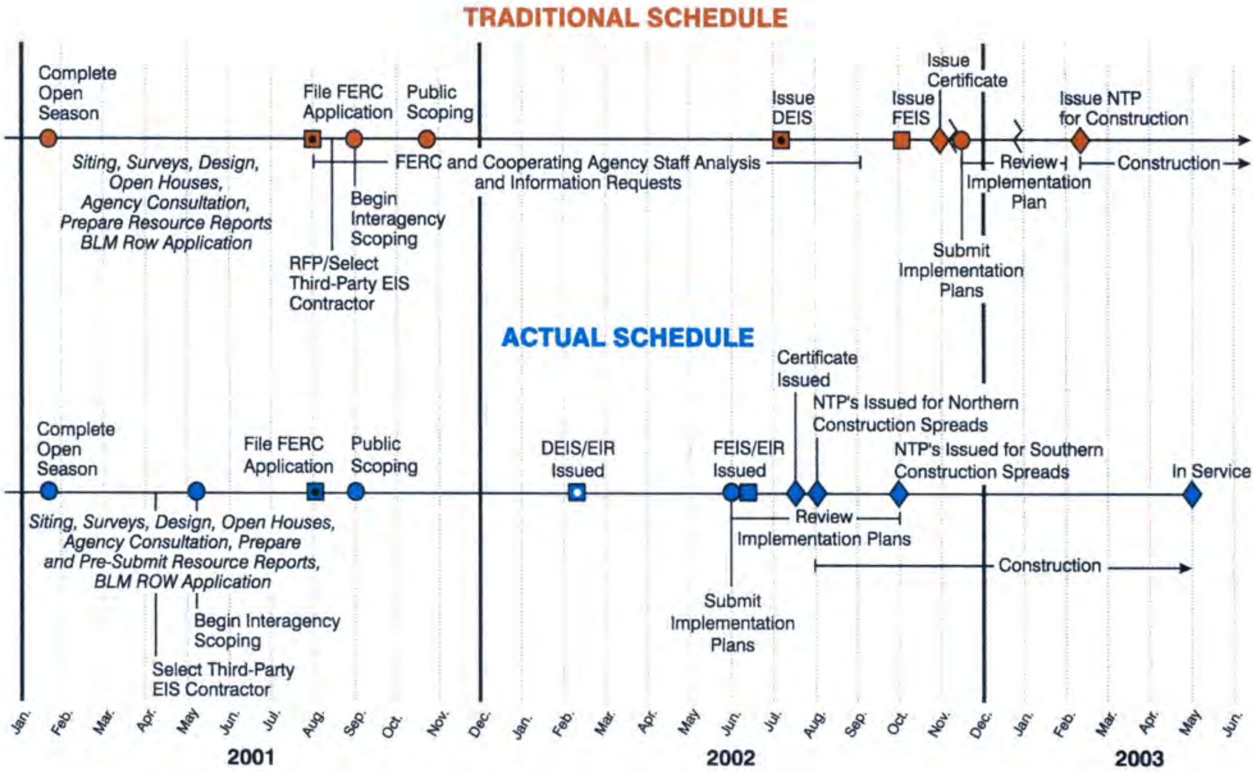

Fig. 2. Kern River 2003 expansion project: Comparison of traditional schedule for FERC environmental review with actual schedule.

variable from project-to-project, so a break in the traditional timeline is denoted. A more brief illustration of the actual schedule with key milestones is also provided in Fig. 3. It is also noted the original conceptual schedule provided for a June 2002 start of construction as the best case, whereas construction actually began in early August of that year.

STRATEGIES FOR EXPEDITING THE SCHEDULE

In view of a traditional regulatory schedule clearly precluding a May 2003 inservice date, Kern River approached the FERC and BLM for informal pre-application consultation and guidance in February 2001. It was apparent that the only viable options or strategy involved identifying means to move as much of the effort normally done in the post-filing period back to the pre-filing phase.[1] Kern River began its schedule analysis by beginning with the May 2003 inservice date, and working back to target key milestones toward the start-date that was effectively February 2001. Key milestones included submittal of the 7(c) Application, completion of the EIS/EIR, receipt of the FERC Certificate, issuance of NTPs, and time required for construction. Given the special circumstances associated with the California energy crisis that existed in 2000/2001, the FERC supported Kern River's efforts to expedite the process, so long as the FERC and cooperating agencies could meet their regulatory responsibilities under existing Acts and regulations. The following is a summary of the more significant measures used by Kern River to achieve this schedule.

1 The process of moving efforts from the post-filing phase into the pre-filing phase is similar to the current FERC Pre-Filing Process.

MEETING THE INSERVICE DATE

Pre-filing period

Defining a fixed project

To accelerate its pre-filing efforts, including submittal of the 7(c) Application by August 1, 2001, Kern River began by defining the pipeline loop configurations and locations, along with the compression expansion, to such extent that they would not be subject to significant changes; or "fixing" the project. Filing a system that would have to substantially change later would cause delays after the filing and completion of the EIS. In its flow analysis and evaluation of combinations of looping and compression, Kern River was also able to avoid having to loop through the Wasatch-Cache National Forest in Utah, and through the developed portion of the Las Vegas metropolitan area, which had significant new and planned development over the last decade since the original mainline was installed. Figure 1 shows these segments. The time required for survey, design, permitting, and construction through these areas was considered a fatal flaw in meeting the May 2003 inservice date. By avoiding these segments, Kern River was best able to expedite the engineering and design of a "fixed" project.

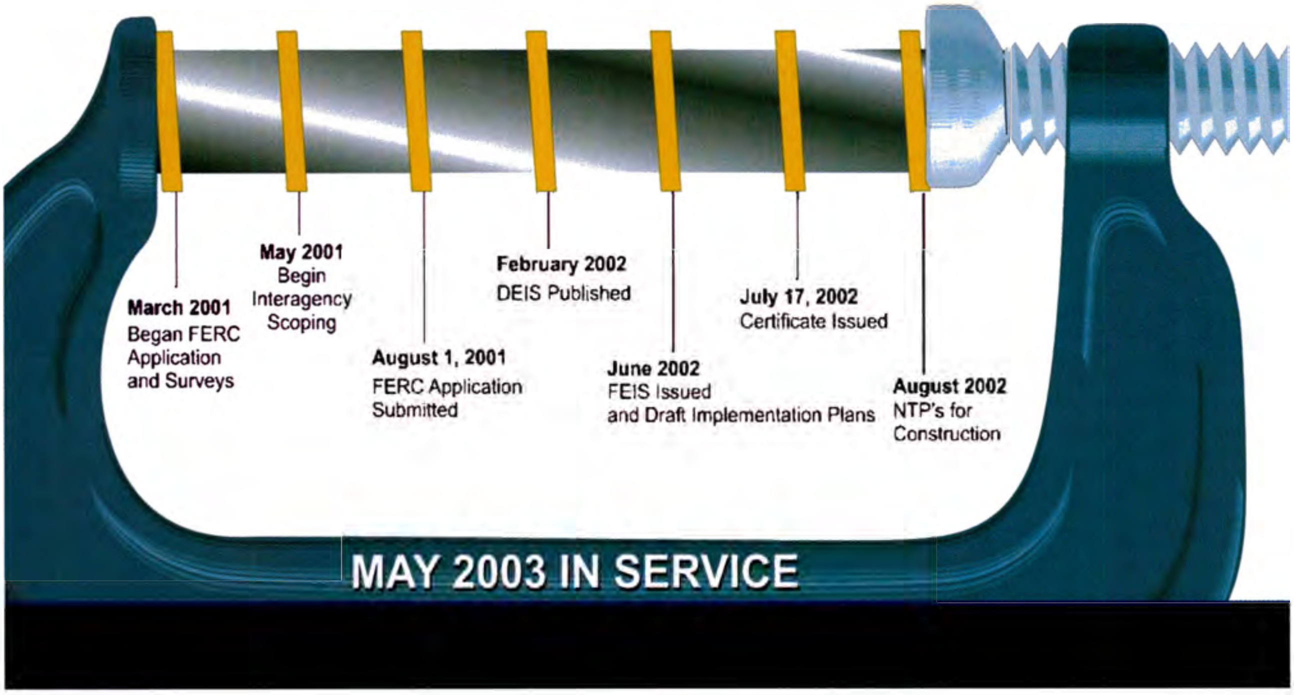

Fig. 3. Key mileposts for Kern River 2003 expansion project.

Kern River also proposed to construct the expansion pipeline adjacent to the original pipeline, which enabled Kern River to utilize existing data and utility corridors, further expediting engineering and design. A major advantage to Kern River was that much of the environmental and engineering data (including biological, cultural and paleontological survey data) were archived from the original project in documents such as the original EIS/EIR (1987, 1988). In addition, except for some recent new and planned development near Salt Lake City, and a limited number of changes in special management units on federal lands,[2] land use remained basically the same since construction of the original pipeline system. Moreover, Kern River had most private landownership records and excellent relations from the original project and throughout operations so that the proportion of voluntary survey permissions and easement acquisition was very high. Another major factor on federal lands was that the existing ROW was now mainly within designated utility corridors in current Resource Management and Forest plans, which allowed Kern River to avoid requesting more formal and time-consuming amendments or exceptions to those plans. These factors allowed the design and surveys to be expedited by Kern River as compared to a "Greenfield" type project.

Kern River also conducted a constructability and alternatives analysis early in the planning phase with input from agencies, so as to minimize the likelihood of agencies or other stakeholders proposing additional alternatives. Several route alternatives were made to address land use and regulatory changes, but for the most part the expansion system could adhere to the standard design of a 25-foot parallel offset of the new loop from the existing pipeline. As such, alternatives were a comparatively minor issue with minimal risk of later system changes impacting the schedule.

As a final effort to "fix" the project, Kern River defined the construction schedule early in the process, with environmental constraints in mind. Completing construction and restoration in the northern sections in Utah and Wyoming by the winter of 2002 was critical, especially in the higher elevations northeast of the Salt Lake Valley. However, winter construction in the Mojave Desert region was ideal so construction could occur through the winter of 2002/2003 into the early spring. To account for these different ecosystems, Kern River established the logistics for six construction spreads beginning in the summer of 2002 in Utah and Wyoming, with four additional spreads to kick-off in the fall of 2002 to complete construction in Nevada and California.

Early environmental and cultural surveys

After defining the project, Kern River conducted a "gap" analysis to identify additional information needs. Kern River's existing databases and original EIS/EIR were reviewed to more accurately scope the effort needed for environmental surveys and prepare a complete ER for the expansion project (consisting of the 12 resource reports under the current filing requirements contained in 18 CFR 380.12). Civil and environmental surveys were then conducted based on

2 Land use changes on federal lands are further discussed in the paper entitled *Restoration on Pipeline Right-of-Way Through Red Rock Canyon National Conservation Area* included in these proceedings.

knowledge of existing resources and potential areas of concern. To reduce the time required for preparing the 7(c) Application, surveys proceeded almost parallel with resource report preparation, engineering design, and the initial agency consultation.

There were three special considerations that made the survey efforts more intensive than may originally have been assumed, including broader or more strenuous environmental survey requirements, the need to conduct surveys in advance of agency input, and the role of climate in identifying certain species. The first consideration was that even though the loops were generally offset from the existing pipeline by 25 feet, meaning that part of the original 50 foot permanent ROW as well as additional area in the original construction ROW and ATWS was previously disturbed and surveyed, essentially all new biological surveys were necessary to meet the current requirements and needs of the USFWS and state wildlife agencies for Endangered Species Act compliance and BLM and state clearances.

Due to the need to conduct new surveys and file the 7(c) Application by August 1, 2001, in some cases, surveys had to proceed before all the resource agencies provided formal requirements for specific species and approvals of survey methodologies. Where specific species information was lacking, general biological surveys were conducted to identify suitable habitat, including dominant vegetation and the presence of wetlands and streams. As such, some additional follow-up surveys were required at locations identified as suitable habitat for sensitive species such as the pygmy rabbit in northern Utah, listed as sensitive by the BLM. Likewise, extensive cultural resource surveys needed to proceed in 2001 before all Native American consultation was completed and finalization of a Programmatic Agreement (PA). The PA was initiated by the FERC with the BLM, other federal owners, designated Indian tribes, and the individual State Historic Preservation Offices (SHPOs) under the Historic Preservation, American Indian Religious Freedom, and other acts and executive orders pertaining to cultural resources. There was also other archaeological excavation permitting to be obtained from the State of Utah. The PA was executed on January 12, 2002 well after the cultural survey effort began in 2001. Both biological and cultural resource surveys were dynamic and required mobilization of additional resources, including follow-up biological surveys extending in specific segments into 2002 along with the intense cultural resource surveys and testing.

Climate also was an important factor in completing the environmental surveys. The Mojave Desert Region from southern Nevada south to California presented ideal winter survey conditions, except for some narrow spring windows for specific plants and birds of concern. However, it would have been practically impossible to conduct surveys during the late months of 2001 in northern Utah and Wyoming under normal conditions due to snow cover as well as plant dormancy and target species inactivity. A late onset of winter conditions in the fall of 2001 was an added benefit to help maintain the schedule for civil and environmental surveys, and for completing the primary restoration work.

Early and often agency consultation

Concurrent with the field surveys, Kern River conducted pre-filing consultation with regulatory agencies and elected officials in the four-state project area as well as a pro-active landowner negotiation program to obtain voluntary survey permissions and easements. As part of this effort, Kern River initiated a series of Open House meetings by June 2001 to further inform landowners and other stakeholders, and obtain comments. Preparation of the Resource Reports and detailed design was also initiated by March 2001 in view of the August 1 filing date. Kern River also established a project website which could be utilized by the FERC and cooperating agencies before the FERC could assign a docket number and establish its website, which the FERC now typically does under the current Pre-Filing Process.

Of equal importance to maintaining the schedule was the pre-filing effort of the FERC and BLM. As part of the pre-filing effort, the FERC procured a third-party EIS contractor and initiated the interagency scoping in May 2001, in advance of the August 1 Application. The BLM also mobilized a project assistance contractor early. In addition, the CSLC issued its notices of preparation of a draft EIR and for public meeting in July in advance of the FERC filing. Under a traditional schedule, these steps would have occurred after the filing was deemed complete, which would have added at least two months or more to the post-application period. In addition, FERC staff worked cooperatively with Kern River by allowing Kern River to submit individual draft resource reports to the FERC staff. This procedure provided several major benefits:

- Provided the FERC environmental information to support the interagency scoping and begin work on sections of the Draft EIS/EIR (DEIS/EIR);
- Provided Kern River early comments to better address data completeness and work toward resolution of issues;
- Provided better assurance that the formal August 1 filing would be deemed complete;
- Reduced FERC staff time needed to review the ER after filing; and,
- Enabled the FERC to proceed more directly to public scoping and DEIS/EIR preparation since most of the material was already on hand.

By "fixing" the project location and components, conducting initial surveys in advance of all formal agency input with allowances for follow-up surveys, and consulting with agencies and stakeholders early in the pre-filing phase, Kern River was able to submit its Application to the FERC on August 1, 2001. Although these efforts required the commitment of additional resources, the Application was deemed complete, saving the project time in the post-filing period. Kern River had also submitted its application to the BLM for amending the Original Grant of Right-of-Way to initiate NEPA review, and its Notice to the CSLC to begin the CEQA process.

With respect to completeness of the ER, there were some data that could not be included at the time of the FERC filing that were needed to complete the Final EIS/EIR (FEIS/EIR). These included survey results for some species of concern and receipt of detailed comments from the federal and state resource agencies needed for the USFWS to issue its Biological Opinion (BO), required as part of the FEIS. Due to the number of potential sites, the fact that the PA was still being developed and federal and state cultural resource clearances had yet to be received, cultural resource field inventories had also not been completed by the time of the FERC filing.

It was important in the ER to identify these gaps, present justification, and provide a schedule for completion, and determining otherwise that the ER met or exceeded the minimum filing requirements. Several information requests were received after filing, to which Kern River responded with supplemental filings, but major gaps or identification of significant new issues were avoided. Kern River and the agencies could focus instead on providing more specific details and resolving issues resolution as the DEIS/EIR was developed. In addition, Kern River proceeded with acquiring other permits and approvals.

Post-filing period

The Post-filing Period extended from the time of the August 1, 2001 submittal of the 7(c) Application to the receipt of the FERC Certificate on July 17, 2002. During this period, the critical path was that the EIS/EIR proceed and be completed in minimal time by the FERC, BLM and CSLC staff, while Kern River concurrently proceeded with completing various mitigation plans, acquiring other permits and approvals, and the detailed design and ROW acquisition programs.

Critical path – EIS/EIR

In general, the philosophy of Kern River, the FERC and cooperating agencies was basically to "resolve the issues now rather than later." The FERC and CSLC conducted a series of six public scoping meetings beginning in August to provide project information and identify potential public concerns. The meetings and public scoping were completed in September, several months sooner than would have occurred under a traditional schedule. Kern River's schedule benefited from the expedited meetings, as well as relatively few public comments. The amount of substantive comments on environmental issues received during the scoping process or introduction of more controversial issues was comparatively minor for a project of this size.

While a range of issues or impacts were addressed in the ER and EIS/EIR, in terms of the amount of expended effort and the degree of agency involvement, critical issues for the Kern River 2003 Expansion were as follows:

- **Species of Concern and Compliance with the Endangered Species Act:** In conjunction with the DEIS/EIR, species of concern needed to be addressed with the federal and state agencies. Before receiving the FERC Certificate, the USFWS would have to issue a BO for the project, and preferably at about the time the FEIS/EIS was complete so as to meet schedule demands. Consultation with the USFWS regarding the BO required intense effort by Kern River, including completion of follow-up surveys and submittal of data as supplemental filings. The most critical issue for the BO was the need to address on-site and off-site compensatory mitigation for the Desert tortoise. The Desert tortoise was the primary biological issue throughout the Mohave Desert portion of the system, which extended from southern Utah throughout the 307-mile portion of the system in Nevada and California. Compensatory mitigation included negotiation of mitigation ratios, which ranged from 1:1 up to 5:1 on an acre-to-acre basis, the highest ratios being for previously undisturbed ROW in Desert tortoise critical habitat. The acreage amounts were established based on the design and ROW/workspace dimensions along the loops, as well as other temporary use areas such as pipe yards. In addition to establishing mitigation ratios, Kern River also had to develop enhancement and endowment funding levels based on predicted acreage disturbances and consultation with the USFWS, Desert Tortoise Preservation Committee, and California Department of Fish and Game (CDFG).[3]
- **Cultural Resources and Historic Preservation Act Compliance:** The need to complete the PA as indicted above was a critical path. There were about 150 sites that needed to be evaluated for potential eligibility, and excavated, treated or otherwise mitigated before construction could occur in the vicinity. Extensive consultation was required with the FERC, BLM, Advisory Council, the individual SHPOs, and participating Native American organizations to finalize the PA and address those sites.
- **ROW Restoration and Noxious Weed Control:** Restoration of native vegetation on the ROW, including the control of certain noxious weeds, was

3 Refer to the paper *Desert Tortoise Mitigation; Lessons Learned, a Case Study of the Kern River 2003 Expansion Project* included in these proceedings for a more detailed analysis of Desert tortoise mitigation.

a project wide issue on public and private lands. Because restoration and noxious weed control was recognized as an issue early in the process, Kern River distributed the reclamation plans prepared for the original Kern River system to the respective state and district BLM offices and the Natural Resources Conservation Service (NRCS) offices during the pre-filing stage, and solicited comments on the effectiveness of the original restoration procedures and results, since the existing ROW provided that opportunity. Generally, the original restoration for the northern sections was found to be largely successful. As such, the original plans could be adapted to the expansion project, allowing for some revision to reflect the current FERC Plans and Procedures and changes or improvements to seed mixes, based on experience and changes in BLM or NRCS guidelines or practices in more recent years. However, the agencies advocated more intense revegetation effort for the desert sections from southern Utah to California, involving direct seeding and increased use of salvaged and locally available succulent plants, such as cacti. Likewise, the CDFG had similar expectations. Owing to the project-wide importance of restoration, the agencies expected that the State restoration plans be completed by Kern River at least in draft form for the DEIS/EIR, and be final to include with the FEIS/EIR. Kern River put forth the appropriate effort to accomplish this.

- **Design and Compressor Stations:** As mentioned in the discussion of pre-filing efforts, fundamental to implementing the strategy to expedite the schedule was the need to "fix" the design or system as early as possible so that significant changes did not occur later, which would have created the need for additional supplemental filings and required more interagency iterations of the EIS/EIR. All of this means more time for the certification as well as the post-certification process, in the form of additional conditions for which the sponsor needs to address and submit for review and approval before NTPs can be issued to begin construction. Given the nature of the pipeline looping, and well defined, viable route alternatives or variations that were identified and addressed before filing the 7(c) Application, Kern River was largely able to avoid such changes later in the process. significant changes due to other parties proposing variations that had not been adequately addressed and might be adopted were also avoided, though there were some minor route variations.

During the post-filing period, Kern River addressed minor route variations and changes to compressor stations to resolve conflicts with other planned development. One notable example of avoiding planned development by other parties involved the proposed Legacy Highway Project in part of Salt Lake County, Utah, which may have precluded Kern River utilizing its proposed alignment. In addition, Kern River addressed additional collocation with a powerline corridor. A new location for the Salt Lake Compressor Station also became necessary. A supplemental filing was made in October 2001 due to Kern River's inability to reasonably negotiate purchase in fee of property for the new Salt Lake Compressor Station for the originally proposed site. Further analysis of available sites was conducted and an alternative site approximately four miles from the original site was selected as the preferred site. It was important that Kern River had addressed alternative sites in its Application so that additional analysis was minimized in the post-filling period. The relocation of the Salt Lake Compressor Station required additional environmental analysis, survey, and design, and affected some re-design and relocation of launcher and receiver facilities on the upstream and downstream segments. However, the time required to accommodate this design change was minimized and incorporated in the DEIS/EIR. In general, the working philosophy was to avoid or minimize changes to the construction ROW or ATWS dimensions and locations and facility sites, so that the construction footprint under review would be the one approved and in which Kern River would construct.

The DEIS/EIR was issued in February 2002, after which a series of public comment meetings was held in early April, with a comment period through April 15, 2002. Given the nature of the Kern River 2003 Project, the pre-filing interagency scoping and submission of draft resource reports, and ongoing agency coordination, relatively few comments were received, and no new significant issues arose. Most of the comments were from other permitting agencies focusing on items within their jurisdiction and interest in greater detail. Kern River took the initiative to provide the FERC with Kern River responses to all relevant comments received, with the intent to provide additional information for the FERC to consider in its and the cooperating agencies' review and response to comments. This approach was effective in helping to reduce the time for completing the FEIS/EIR, and acquiring those other permits and approvals.

Other permits and approvals

Generally, the acquisition of other federal, state, and local permits and approvals identified in Table 1 proceeded parallel to the EIS/EIR process. While details and actual schedules for all these permits and approvals are not provided herein, key permits and approvals that were, or are often, the most time-critical for Kern River and similar projects in the U.S. are noted below:

- **U.S. Army Corps of Engineers, Section 404 Clean Water Act (CWA):** The preference is to submit the Section 404 application at or close to the time of submitting the FERC 7(c) Application, given the importance of the CWA to the FERC's responsibilities as lead agency. The data on wetlands and waterway crossings and mitigation presented in the Section 404

Table 1. Major Permits, Licenses, Authorizations, and Clearances for the Kern River 2003 Expansion Project[1]

Agency	Permit/Clearance/Approval	Status as August 1, 2001
Federal		
Federal Energy Regulatory Commission	Certificate of Public Convenience and Necessity	Filed August 1, 2001
U.S. Bureau of Land Management	Right-of-way Grant amendment under Minerals Leasing Act for all Federal lands	Filed March 26, 2001
U.S. Forest Service	Special Use Permit for Dixie National Forest	Filed April 6, 2001
U.S. Fish and Wildlife Service WY, UT, NV and CA offices	Section 7 consultation for Federally protected species	Coordination initiated March 1, 2001
U.S. Army Corps of Engineers Sacramento and Omaha Districts	Nationwide Permit 12 for installation of utility lines. IP for Yellow Creek	To be Filed (TBF) August 31, 2001
U.S. Bureau of Reclamation	Two road crossings in Utah	TBF October 15, 2001
State of Wyoming		
Wyoming Department of Environmental Quality	Authority to construct and operate – Air permit	TBF August 15, 2001
Wyoming Game and Fish Department	Clearance for state listed species	Initiated March 1, 2001
Wyoming State Parks and Cultural Resources	Clearance under Section 106	Initiated March 1, 2001
Wyoming Department of Environmental Quality	Submit NOI under General Permits	TBF May 1, 2002
Wyoming Department of Environmental Quality	General permit for discharge of hydrostatic test water	TBF March 1, 2002
State of Wyoming Hwy District 3	State Highway Crossings	TBF October 15, 2001
State of Utah		
Utah Division of Wildlife Resources	Clearance for state listed species and wildlife	Initiated March 1, 2001
Utah Dept. of Environmental Quality-Water Quality Division	Submit NOI under General Permits UTR100000 and UTG070000	TBF May 1, 2002
Utah Division of Water Rights	Water rights transfer for hydrostatic testing	TBF February 1, 2002
Utah Dept. of Environmental Quality-Air Quality Division	Operating permit	TBF August 31, 2001
Utah Dept. of Environmental Quality-Water Quality Division	Stream Alteration Permit	Deferred July 12, 2001
Utah State Historic Preservation Office	Clearance under Section 106	Initiated March 1, 2001
Utah Department of Transportation	State Highway Crossings	TBF October 15, 2001
State of Nevada		
Clark County Health District Air Quality Division	New Source Review; Authority to construct and operate – Air permit; Dust Permit	TBF August 31, 2001
Nevada Natural Heritage Program	Clearance for state listed species	Initiated March 1, 2001
Nevada State Historic Preservation Officer	Clearance under Section 106	Initiated March 1, 2001
Nevada Division of Environmental Protection Bureau of Air Quality	Air quality operating permit	TBF August 31, 2001
Nevada Division of Environmental Protection Bureau of Water Pollution Control	Surface water discharge permit for hydrostatic test water; General storm water permit	TBF February 15, 2002
Nevada Department of Transportation	State Highway Crossings	TBF October 15, 2001
State of California		
California State Land Commission, California Environmental Quality Act (CEQA)	Surface Leasing of State Lands, Mojave River Crossings	Filed May 17, 2001
California Dept. of Fish and Game	Clearance for state listed species and wildlife	Initiated March 1, 2001
California Dept. of Fish and Game	Stream alteration permit	TBF August 31, 2001
California State Water Quality Control Board	NOI for stormwater coverage under Water Quality Order 99-08-DWQ	TBF March 1, 2001
Colorado River Basin Regional Water Quality Control Board	Waiver to discharge hydrostatic test water	TBF February 15, 2002
California Historic Preservation Office	Clearance under Section 106	Initiated March 1, 2001
California Dept. of Transportation-District 8	State Highway Crossings	TBF October 15, 2001
California Dept. of Transportation-District 6	State Highway Crossings	TBF October 15, 2001
Local Permits-Wyoming		
Union Pacific Railroad	Railroad Crossing	TBF December 15, 2001
Uinta County Road Department	County Road Crossings	TBF December 15, 2001
Local Permits-Utah		
Summit County Public Works	County Road Crossings	TBF December 15, 2001
City of Coalville	Street Crossings	TBF December 15, 2001
Salt Lake County Public Works	County Road Crossings	TBF December 15, 2001
City of West Valley	Street Crossings	TBF December 15, 2001
Salt Lake, Garfield & Western Railroad	Railroad Crossing	TBF October 15, 2001
Western Pacific Railroad	Railroad Crossing	TBF October 15, 2001

Table 1. (continued)

Agency	Permit/Clearance/Approval	Status as August 1, 2001
Local Permits-Utah		
Summit County Public Works	County Road Crossings	TBF December 15, 2001
City of Coalville	Street Crossings	TBF December 15, 2001
Salt Lake County Public Works	County Road Crossings	TBF December 15, 2001
City of West Valley	Street Crossings	TBF December 15, 2001
Salt Lake, Garfield & Western Railroad	Railroad Crossing	TBF October 15, 2001
Western Pacific Railroad	Railroad Crossing	TBF October 15, 2001
Local Permits-Utah		
Union Pacific Railroad	Railroad Crossings	TBF October 15, 2001
City of West Jordan	Street Crossings	TBF December 15, 2001
City of South Jordan	Street Crossings	TBF December 15, 2001
City of Bluffdale	Street Crossings	TBF December 15, 2001
Utah County Road Dept.	County Road Crossings	TBF December 15, 2001
Juab County Road Dept.	County Road Crossings	TBF December 15, 2001
Millard County Road Dept.	County Road Crossings	TBF December 15, 2001
Beaver County Road Dept.	County Road Crossings	TBF December 15, 2001
Iron County Road Dept.	County Road Crossings	TBF December 15, 2001
Washington County Road Dept.	County Road Crossings	TBF December 15, 2001
Local Permits-Nevada		
Clark County DOT	County Road Crossings	TBF December 15, 2001
Union Pacific Railroad	Railroad Crossings	TBF October 15, 2001
Local Permits-California		
San Bernardino County	Franchise License	TBF February 1, 2002
San Bernardino County Transportation Dept.	County Road Crossings	TBF December 15, 2001
Union Pacific Railroad	Railroad Crossings	TBF October 15, 2001
BN&SF Railway Company	Railroad Crossings	TBF October 15, 2001
San Bernardino County Flood Control District	Channel Crossings	TBF October 15, 2001
City of Barstow	Road Crossings	TBF December 15, 2001
Kern County Road Dept.	County Road Crossings	TBF December 15, 2001

[1] From Resource Report 1, August 1, 2001, Kern River Gas Transmission Company, FERC Docket No. CP01-422-000.

Application are also important to the FERC's analysis. Rather than designate a lead USACE District, in this case Kern River was required to obtain authorizations from three districts: the Omaha District for Wyoming, the Sacramento District for Utah and Nevada, and the Los Angeles District for California. With the exception of some special conditions added to the Nationwide 12 Authorization by the Sacramento District, authorizations were received under the Nationwide permit program versus requiring Individual permits. Wetlands, while important, were not a major issue and did not require compensatory mitigation. Wetlands traversed by the project were not extensive, and were mainly emergent wetlands or riparian fringes on lands subject to grazing, where restoration of the disturbed area provided sufficient mitigation. The total acreage impact to wetlands was less than 60 acres for the whole project, with no permanent fill or loss of wetlands. Similarly, the two major waterway crossings with high aquatic value utilized horizontal directional drilling, and crossing of the remaining perennial, sensitive waterbodies avoided periods of fish spawning, and utilized specialized techniques such as dry fluming as provided for in the FERC's *Wetland and Waterbody Crossing Construction and Mitigation Procedures.*

- **Air Permitting for New Compressor Stations:** The Clean Air Act permitting, as delegated to the states, was also a critical path to construction. This was due to the emissions offsets that needed to be addressed for the Salt Lake Compressor Station, and other related minor design and equipment-type modifications to the stations in Utah and Nevada that required intense coordination and negotiations with these states.
- **Plan of Development:** The BLM also required a Plan of Development (POD or Construction, Operations, and Management Plan) to support its and other federal land management agencies' review for the amendments to the Grant of Right-of-Way. The POD for the expansion project was adapted and updated from the original plan for the Kern River system and submitted in October 2001 so the BLM and USFS could review the plan in concert with preparing the EIS.

As noted above, the other most time-sensitive approvals needed for the project were the cultural resource excavation permit in the State of Utah, establishment of final mitigation, and completion of the BO.

Implementation plans and notices to proceed

Implementation plans address those additional FERC conclusions and recommendations or conditions presented in Section 5 of the EIS/EIR, and included with the Certificate, that need to be addressed before NTPs are issued. The implementation plans are incorporated into the FERC Certificate as additional information, responses, plans, or other related supplemental information the sponsor is to provide for review and approval before an NTP is issued for construction. The plans include a formal plan for environmental compliance (environmental inspection program). Normally, implementation plans are prepared after the Certificate is issued. Depending on the number and types of conditions to be addressed, or changes to the project design or construction schedule, the time period can be highly variable and sometimes lengthy. Since the Certificate was issued in July 2002, and Kern River needed to be able to begin construction on the northern spreads in August of that year, there was essentially no time to prepare implementation plans under a traditional schedule.

To maintain the project schedule, Kern River proceeded with preparing the implementation plan for the six northern spreads shortly after the DEIS/EIR was issued. In view of the intense support to the FERC and CLSC staff to address issues and file supplemental information and plans, the number of and type of conditions were comparatively small and could be anticipated. The conditions in the FEIS/EIR did not change materially from the DEIS/EIR. In fact, some conditions in the DEIS/EIR were eliminated by Kern River's responses to comments and supplemental information provided during the public comment period. The FERC agreed to review the draft implementation plan informally by submitting drafts in May and June 2002, so that by the time the FERC issued the Certificate, Kern River could quickly obtain final review and approval of the implementation plan and NTPs for construction. In addition to reviewing the draft implementation plan, it is also significant that the FERC allowed Kern River to receive an NTP for the northern spreads separately from the southern spreads, in view of the construction schedule and conditions more applicable for the Mojave Desert, and in some cases by individual spread. In this manner a separate implementation plan could be submitted later for the four southern spreads so that winter construction could proceed in October and November of 2002. The willingness of the FERC and BLM in issuing individual NTPs for groups of spreads versus holding review for one NTP for the entire project was key to making this construction schedule possible.

In addition to the timing of the implementation plans, another important consideration for the NTPs involved pipe yards and off-loading areas. In order to begin construction on a given spread where pipe stringing can immediately proceed behind trenching, sufficient pipe had to be delivered and stockpiled on the spreads in advance. In some cases, the FERC granted early approval to allow use of specific yards prior to the general NTPs, so that pipe could be stockpiled by the time ROW earthwork began. It was important that Kern River addressed these sites in its 7(c) Application so they were covered in the FEIS/EIR and Certificate for this to have been possible. Kern River also identified sites during the Pre-Filing Process that had prior, in-kind uses, some of which were used on the original project and included these in the Application.

Issuance of the NTPs was also dependent on the POD for the BLM. In the weeks before construction, it was found that in some cases the POD originally submitted needed to be revised for consistency with some final provision of the FEIS/EIR, FERC Record, and other federal and state permitting. In order to assure consistency with the FEIS/EIR for the BLM to also issue NTPs for construction, Kern River spent intense effort to update parts of the POD before BLM issued its NTPs.

Construction period

To maintain the May 2003 inservice date, construction likewise had to be expedited, although it was originally accepted that the schedule for Certification, permitting and obtaining NTPs was the most critical path, with the highest risk for delays. As described, Kern River established 10 construction spreads, six in the north for summer and fall construction in 2002, and four in the south for winter/early spring construction in 2002/2003. The most critical environmental considerations were avoiding or minimizing periods of restricted activity (or blackout periods); maintaining progress on archaeological testing ahead of construction in some sections of Utah and California; minimizing the need to request variances; having a process in the field for more routine and quick turnaround for variance requests; and, in general maintaining a high level of compliance and avoiding stop-work incidents or delays.

Avoiding or minimizing blackout periods was of great concern, and was a key part of the data analysis and agency consultation early in the ER preparation. A number of potential blackout periods would have been encountered had construction on the northern spreads begun in June as opposed to the actual start date in August. These blackout periods were associated with Spring activity of sensitive species such as Sage grouse mating and nesting, raptor nesting, deer fawning on some special federal land management units, or late spring/early summer spawning periods for coldwater fisheries, notably the Bonneville cutthroat trout. Construction during blackout periods may have required skipping segments of the ROW for later construction, or moving around streams and installing crossings later in the year; rather than proceeding with the mainline construction, "tieing in" small and intermediate-sized crossings and proceeding with cleanup and restoration as they were encountered. Although some special monitoring and mitigation was required for species such as the Utah prairie dog, blackout periods were largely avoided with the August start date.

Late fall/early winter blackout periods for designated big game wintering areas in a number of the higher elevation areas beginning as early as the first part of November were also of concern. However, Kern River maintained construction progress, and by early November the remaining work was largely completed. By this time, crews were working on revegetation, remaining hydrotesting, final tie-ins, completion of remaining valve and test lead installations, and signage. In addition, the onset of winter conditions was late in 2002, so big game had not yet concentrated in the wintering ranges, which also allowed work to be completed prior to big game concentrating in any of these areas.

The most widespread compliance issue, with the potential to impact the construction schedule for the southern spreads, was the Desert tortoise. Although by constructing through desert tortoise habitat in the winter, during periods of tortoise inactivity, was a major benefit to the project, recent research demonstrated by Kern River's experience found that there were periods of increased tortoise activity during mild periods with moisture in winter. There was also a special concern for incidental take. There was an underlying concern among the agencies of what they viewed as a comparatively high incidental take of about 30 tortoises during the original project in 1991. The BO recognized there could be incidental take despite Kern River's extraordinary efforts, but allowed for essentially only one take in any 25-mile segment. If this level were exceeded, Kern River would need to renegotiate with the USFWS, with implications for suspending work activities. Kern River was able to avoid renegotiation and work suspension, in that there was only one known take for the project. To achieve this level of protection, in addition to the winter construction schedule, up to 160 tortoise monitors and handlers were employed at the peak of construction. There were other restrictions for tortoises that needed to be accommodated, notably reduced speed limits that affected normal rates of progress for pipe stringing. Construction crews also accommodated sensitive areas that were identified as a result of cultural resources testing and monitoring, as well as finds from the paleontological monitoring. These finds were accommodated with only minimal adjustments to work activities.

The other major consideration for construction was the need to obtain FERC, BLM or CSLC approvals for field variances, mainly in cases where changes to the approved corridor were needed for ATWS, or additional access roads or access road modifications. Kern River funded an agency monitoring program similar to one developed with the FERC in recent years, where most routine variances could be issued at the field level versus through the agencies headquarters. Biological and cultural specialists were also employed on the spreads for the technical surveys of the areas to support the requests for variances, provide specialized support to the environmental inspectors and interface with the agency monitors. This process was used in an effort to expedite approval of more routine variance requests and better maintain compliance.

CONCLUSIONS AND APPLICATIONS FOR OTHER PROJECTS

The Kern River 2003 Expansion Project was unique because of the urgent demands for natural gas associated with the California energy situation in 2000/2001, firm commitments from shippers, and the need to be in service in May of 2003. Given these circumstances, it was necessary to find means to expedite or fast-track the certification and permitting, while complying with all existing regulations. The only feasible options were to move as much of the effort from the post-application periods back to the pre-application period, and complete most of the substantive preparation of implementation plans before the FERC Certificate so that NTPs could be obtained for construction in minimal time after receiving the Certificate. Kern River was also in a more advantageous position to achieve this schedule, committing the resources, because the shippers were fully subscribed for 10 to 15 year contracts, which established need and enabled financing with less uncertainty. Furthermore, Kern River also proposed to construct the expansion pipeline adjacent to the original ROW, which enabled it to utilize existing data and utility corridors. Kern River could in part utilize data archived from the original project, as opposed to the more intense data acquisition that would have been required of a Greenfield project. Kern River was able to expand an existing system with less impacts, in regions where overall land use had changed little since construction of the original system. Kern River could also amend an existing BLM Grant-of-Right-of-Way since the existing ROW was now mainly within designated utility corridors in current Resource Management and Forest plans. This reduced the risk of having to adopt additional major route alternatives, or having other stakeholders or interveners request major changes during scoping or in comments to the DEIS/EIR.

Nonetheless, a significant and highly coordinated pool of resources in environment, engineering, lands and communications or stakeholder outreach needed to be committed beginning in February 2001, if maintaining such a schedule was possible. As described, the concepts employed have similarity to the formal optional Pre-Filing Process in use today from the standpoint of moving more of the analysis and stakeholder involvement to the pre-filing period. However, much longer lead-times would typically be built into the Pre-Filing Process especially for projects of this size. As noted previously, from beginning intense work in late-February 2001, a complete 7(c) Application needed to be filed by August 1 of that year, a period of less than six months.

There are a number of special considerations, reinforced with the lessons learned on the Kern River 2003 Expansion that have applications to other projects. In particular, these lessons are applicable where the sponsor considers utilizing the FERC Pre-Filing Process on a major project and in general is able to commit the resources necessary to fast-track a project. These lessons learned are provided below:

1. Define or fix the Project. To the maximum extent possible, it is necessary to fix or capture the siting and project design as early in the schedule as practical. A thorough constraints and constructability review is required to be able to complete design and ROW and workspace requirements. This review is also needed to avoid basic changes in the system from arising later, which can cost more time and money, and to identify available viable alternatives. Where changes in the system are more likely, identify these types of changes. Concurrently, identify the permits and approvals, the time and effort for acquisition, and costs. Integrate these into a dynamic project schedule, which identifies the critical milestones and the links or sequence of steps and progress that have to occur to meet these deadlines. The benefit of "fixing" the project scope early is to maintain the schedule, and avoid later surprises for both the agencies and the applicant.
2. Consult early and often with involved agencies. Establish and maintain contacts with the FERC and other federal, state and local permitting agencies. Short of asking the agencies to design the project for the applicant, solicit their input. Identify and focus on the key issues and work toward addressing these issues in design and mitigation plans. Maintain contact and momentum once consultation is initiated. Agencies have increasingly become receptive to meeting with the Applicant before applications are made, and this is now part of the formal Pre-Filing Process. Recently, directives have also been issued for federal agencies to expedite energy projects, while complying with regulations, by establishing interagency task groups for energy projects such as through Executive Order 13212 (Office of the President, 2003). State and local agencies have generally become more receptive as well. Build positive relationships and be prepared to implement what sponsor representatives say they will do. This is particularly important in regions where there may have been negative experiences or perceptions with previous projects.
3. Initiate landowner contacts, as well as stakeholder outreach early. Establish an effective lands acquisition program beginning with initial notifications and acquisition of survey permissions from landowners, and obtain their input. After all, they are closest to the lands and often have specific knowledge that may help the project, including knowledge of environmental features such as springs and wells, cultural sites, species of concern, special agricultural practices, future land use plans, and restoration concerns or noxious weed control. Similarly, engage other stakeholders well in advance of the filings through notifications and Open House meetings for the landowners, public, and elected officials. Establishing a project website is also very useful, though not all landowners or other stakeholders have access to the necessary computer resources. Contacting and responding directly to landowners and stakeholders will help expedite the schedule, as opposed to these parties contacting the FERC with comments or questions for it to have to respond.
4. Hiring a third-party EIS contractor, bringing on BLM's project assistance contractor and conducting interagency scoping in advance of the Application was highly benefical to Kern River for a number of reasons. These third-party contractors and interagency scoping and coordination facilitated identification of issues, and helped focus efforts on key concerns that affected design, construction and the scope of mitigation and compensation plans. The interagency scoping, held simultaneously with the sponsor's agency consultation, can also be valuable for getting concurrence on environmental and cultural resource survey scope and methods, and treatment/mitigation procedures.
5. Implement an aggressive and coordinated environmental and civil survey effort. Wherever possible, it is ideal to make engineering adjustments for avoidance or minimization of impacts to environmental features while teams and supervisors are in the field together and landowners can be consulted onsite. This should be documented and included in the resource and survey reports. Encourage and cooperate with the agency field representatives by inviting them to monitor or participate in the surveys, especially when addressing a sensitive resource or site. Field consultation with the parties observing and interacting on the ground is typically the fastest way to resolve issues.
6. Submission of draft resource reports in advance of filing is highly valuable to provide the agencies more complete data earlier in the process. Early submittal of reports also provides time for comment and revision, supports the interagency scoping, and in general allows for earlier identification and resolution of issues.

7. Expedite complete responses to information requests and provide additional information in supplemental filings to better support the EIS development. This reduces those special conditions that will need to be addressed in implementation plans after the Certificate is issued.
8. As the project progresses, continue to consult with the agencies as discussed in item 2 above. Maintain consistent points of contact at the appropriate agency office while the permit applications are developed. Follow through during the review and approval process, and track progress against the master schedule so that any potential fatal flaws or constraints in obtaining permits and approvals can be addressed while there is still an opportunity. It is also noted that some types of permits require engineering plans and drawings, and it is imperative that the engineering team be fully integrated with environmental and lands to best assure completeness and accuracy. Involving the engineering team will also minimize the chances that a permit would be issued with special conditions that require more effort and expense, or create situations where compliance becomes more difficult or even impractical.
9. Where a project requires a separate POD to be submitted to the BLM or other federal land management agency affected for a Grant of Right-of-Way or special use permit, it is important the POD be updated with any changes and track with the FEIS to assure the necessary consistency before the NTPs are issued for construction.
10. Developing implementation plans and cooperating with the FERC for informal review prior to the FEIS and Certificate is of benefit in moving the project along to construction, especially where there are seasonal constraints such as climate. In order to have FERC informally review the implementation plans, the DEIS must to be close to final, with little change expected in the conditions for the FEIS. If the applicant provides substantive responses to comments to the DEIS during the public comment period, the applicant may also minimize the number of conditions from the FEIS that would have to be further addressed in implementation plans before NTPs are received to begin construction.
11. Account for other facilities or use areas that need to be covered in the EIS and Certificate. Conduct cultural and biological surveys for such areas as necessary, including off-ROW areas like off-loading areas, pipe yards, and contractor yards, as well as access roads. For these temporary use areas, maximize use of areas with previous in-kind use wherever possible versus Greenfield-type sites. On other projects, facilities such as these have become the bottleneck for getting NTPs or clearances to begin mainline construction, even though the ROW and stations had already been addressed.
12. Ensure the relevant environmental plans and conditions are incorporated into the construction bid documents to minimize costly change orders and non-compliance situations. For the Kern River 2003 Expansion, environmental permit manuals were prepared for each spread and provided to the construction supervisory personnel and inspection and monitoring staff to supplement the pre-construction briefings and training. These manuals proved useful as guidance and reference documents in the field. Whereas all the details or project record cannot be assembled in one manageably sized document like this, the document provided additional direction as to how to obtain additional guidance and help.
13. Having the agency-monitoring program, in addition to Kern River environmental inspectors and monitors was overall beneficial, primarily for the field approval of more routine types of variances. However, at times the distinction between the roles of agency monitors versus Kern River's environmental inspectors or monitors may not have always been clear or seemed duplicative. The agency monitoring program to the degree used on Kern River may not be necessary on smaller projects (there were as many as three agency monitors at times on one spread) or where the anticipated need for variances is minimal.
14. Manage and maintain compliance throughout construction and restoration to avoid regulatory delays, and so that what is represented in the project records is what actually happens on the ground. Compliance is highly beneficial to the project sponsors and industry as a whole. In the longer-term, compliance on one project may affect future projects proposed in the same region. Where agencies and stakeholders have positive experiences and memories from the previous project, permitting other similar projects should go smoother than where agencies and landowners had negative experiences.

Finally, we emphasize this fast-track approach was not a short-cut and does not represent an overall saving in capital costs through the certification and permitting periods. In fact, the upfront effort and costs and associated commitments tended to be higher than for a project permitted under the traditional schedule. However, being able to meet the inservice date offset other penalties and higher costs that may have been incurred if this schedule could not have been achieved. Similar approaches under the current FERC Pre-Filing Process offer these benefits for meeting firm inservice dates for projects where the demand and need for the project is there, a scope and design of a new system or expansion can be established, and the sponsor is able to commit the necessary resources early.

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REFERENCES

Federal Energy Regulatory Commission. May 2002. Interagency Agreement on Early Coordination of Required Environmental and Historic Preservation Reviews Conducted in Conjunction with the Issuance of Authorizations Construct and Operate Interstate Natural Gas Pipelines Certificated by the Federal Energy Regulatory Commission. Washington, DC. (Available at http://www.ferc.gov).

Federal Energy Regulatory Commission. October 2002. Guidance: FERC Staff Pre-filing Involvement In Natural Gas Projects. Washington, DC. (Available at http://www.ferc.gov).

Federal Energy Regulatory Commission, California State Lands Commission et al. June 2002. Final Environmental Impact Statement/Environmental Impact Report Kern River 2003 Expansion Project. FERC/EIS-0144D. Docket No. CP01-422-000. Washington, DC.

The White House, Office of the President. May 15, 2003. Executive Order Amending Executive Order 13212, Actions to Expedite Energy Related Projects. Washington, DC. (Available at http://whitehouse.gov/news/releases).

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Survey of Electric Utility Rights-of-Way Practitioners

Patricia A. Mullins, Susan M. Tikalsky, and John W. Goodrich-Mahoney

The electric transmission system is often discussed in the popular press as a topic of great concern, particularly in regard to the need for additional transmission lines over the next decade. The objective of this project was to gather information from energy company professionals who are charged with carrying out the task of developing utility rights-of-way (ROW), both for routing new transmission lines and upgrading existing ones. We asked them about current industry practices, technical issues, public involvement, and regulatory conditions affecting routing and upgrading transmission facilities, and about the changes they expect over the next five years. A total of 48 surveys related to electrical transmission lines were analyzed, representing operations in all 50 states in the US. Results show that minimization of environmental impacts is a primary criterion in routing, and this is expected to increase in importance over the next five years, as environmental opposition continues to be a barrier to new development of transmission infrastructure. State-level environmental agencies increasingly are seen as obstacles, and 96% of respondents predicted more government intervention in routing in the future. Even so, the significant ROW issues will continue to be local, such as the need for reduced ROW maintenance costs and easier sharing of ROWs with other utilities.

Keywords: Transmission lines, rights-of-way, transmission-line routing, transmission-line siting, transmission-corridor siting

INTRODUCTION

The adequacy of the nation's electric transmission system is a topic of great concern, particularly the extent of new construction and upgrades required over the next decade to meet increasing energy demand. Regulators, politicians and energy experts support a range of accommodations proposed to expand and strengthen the grid. This effort examines both the day-to-day and long-term challenges associated with the development of transmission-line rights-of-way (ROWs) from the perspective of those energy company professionals who are responsible for carrying out the work of securing the final route. They were asked to provide information on current operating practices, regulatory issues, and social conditions affecting routing and upgrading transmission facilities. Respondents also shared their opinions on anticipated changes in these practices and conditions over the next five years.

METHODOLOGY

Survey characteristics

An eight-page written survey consisting of 46 primarily closed-ended questions was developed for electric and electric/gas combination companies. Survey questions were divided into four categories related to routing new transmission lines and upgrading existing ones: 1. industry practices (determination of need, selection of alternative routes, final selection of route, construction, ownership, maintenance); 2. public involvement (public concerns, company communications, public actions); 3. regulatory involvement (determination of need, selection of alternative routes, final selection of route); and 4. technical issues (new

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technologies, alternatives to new overhead lines, environmental issues).

Respondents were allowed to give multiple answers to many of the questions. Realizing that companies may operate in more than one state, survey participants were asked to consider a representative state and keep it in mind when answering the questions. The final page of the survey consisted of open-ended questions related to anticipated changes that could affect routing transmission lines, as well as a request for additional comments. Surveys took approximately 30–40 minutes to complete. The data were collected from March through October 2003.

Psychometric properties

Reliability

The nature of the questions and their particular grouping and sequence were coordinated in a way that permitted examination of reliability of responses. Some information was solicited in a number of ways, and the responses were examined for consistency and reliability. Questions that asked for rankings were summarized with average ranks, which were checked against the distribution of respondents who had chosen each level of ranking (i.e., the response with a rank of "1" should also have the largest number of respondents ranking it first). The data were found to be remarkably consistent, which is a good indication of reliability of the survey.

Validity

Initial contacts at each company were asked to suggest colleagues who also work with ROW as additional survey participants. Obtaining information from a variety of perspectives (e.g., real estate managers, foresters, transmission-line design engineers) was intended to enhance the validity of the overall scope of responses.

Design

The survey used an observational design to produce information on industry practices and procedures that already exist; that is, a cross-section of energy-industry ROW practitioners provided descriptive data at a particular time. In addition, respondents were requested to predict changes in practices and procedures over the next five years, which added a forecasting design element.

Data analysis

A codebook was created for use in entering data. Data were entered as received, using the predetermined codes. The survey produced numerical data from closed-ended questions, some in the form of rankings, and narrative observations from open-ended questions. Descriptive statistical techniques were used to organize and summarize the data from closed-ended questions. Open-ended questions were coded into categories and the content and frequency of each category was evaluated. As it turned out, the comments themselves were more meaningful in relation to specific questions rather than in categories.

SAMPLE

Selection

Contact information was solicited by telephone for appropriate survey respondents at domestic energy companies—electric and electric/gas combination. The self-administered questionnaires were mailed to 92 individuals at 75 companies. Mailing allowed respondents time to collect information and write additional comments. A number of procedures were used to maximize the response rate:

- the survey was sent only to individuals who agreed to participate when they were initially contacted by telephone,
- a complimentary copy of survey results was offered as an incentive to complete the survey, and
- three reminder telephone calls followed the initial mailing at approximately four-week intervals.

Operations in every state in the US were represented in the sample. A total of 48 surveys were analyzed. This represents a 52% response rate, with respondents' companies owning a median of 3, 317 miles of electrical transmission lines (range 50–17,000) and a median of 9,500 miles of electrical distribution lines (range 20–95,268).

Demographics

The demographic characteristics of the survey respondents were well balanced. Respondents were from an equal number of private and public, local and regional, distribution and transmission companies, as well as three regional transmission organizations (RTO). The greatest proportion of ROW practitioners who responded to the survey work primarily in the area of real estate management and ROW acquisition, with somewhat smaller but equal proportions working in transmission-line routing and planning, design and construction, maintenance and forestry, and environmental permitting and compliance. They are a highly experienced group, with half of the respondents having between 6.5 and 17.5 years on the job (median 10 years). This level of experience reveals that they have seen many changes in the past and are uniquely qualified to predict what will happen in the future.

In order to gain insight into whether responses were related to an individual company's strategic positioning, the survey included a request to choose the best descriptor from a list of four business practices. Forty-seven of the 48 respondents characterized their companies either as focused on maintaining stability or being the best in the business, qualities that have been associated with the most successful energy companies (Coyne and Hartshorne, 2003). Only one respondent described his company as seeking to expand the geographical range of its services and no companies were said to be expanding business into non-traditional areas.

RESULTS

Respondents represented 41 companies that have a total of approximately 120 transmission lines constructed over the last ten years or currently under construction and approximately 107 lines proposed. The majority of lines that have been built are 69–138 kV; however, there is an increase in the proportion of lines greater than 345 kV that respondents are proposing to build.

Industry factors

Recent media coverage regarding the adequacy of the nation's electric transmission system has focused on two central issues as obstacles to improvement—capital and routing. The financial issue has been addressed by advocating for an increase in allocation of capital for infrastructure. The issue of routing has been addressed by advocating for an increase in the role of the federal government, notably the Federal Energy Regulatory Commission (FERC) (Berenson, 2003; Stone, 2003).

The perspective of the survey respondents, the people actually assigned to the task of obtaining the ROW to accomplish transmission-line routing, is a bit different. Eighty-eight percent of respondents said that their company encountered opposition from the public and from landowners, and 65% cited environmental obstacles as barriers. Only 25% cited economic factors as a barrier to transmission-line construction, and 52% cited delays due to the regulatory process. So while economic factors figure prominently in the broad picture of expanding the transmission infrastructure, the public and landowners present the most significant obstacle to energy-company employees charged with carrying out the routing of a line.

The majority of respondents (69%) said that local utilities have primary responsibility for determining the need for new transmission lines in their service area and that local utilities, not RTOs, identify viable preferred and alternative routes (71%); however, there is some expectation that RTOs will take on more of these responsibilities in the next five years.

Ninety percent of respondents continue to employ hard-copy maps to identify and assess transmission-line routes. GIS is used by 73%, remotely sensed data by 38%, and other types of computer software by 23%. Numerous comments were made about looking forward to increased use of GIS, remote sensing, and other sophisticated data-collection techniques.

Respondents identified the most important criteria used in selecting specific routes for transmission lines, in order of priority, as avoidance of residential areas, level of public opposition, and minimization of environmental impact (Table 1). Forty-four percent of respondents chose one of these three criteria as their most important, and a majority perceived them as increasing in importance. It should be noted that 19% of respondents stated that minimization of electric and magnetic field (EMF) exposure as a routing criterion was decreasing. At the time of the survey, EMF was not a highly publicized issue. Whether the lack of media attention may have influenced the respondents' judgment of EMF in relation to the other criteria is not known.

Table 1. Ranking of routing criteria

Criteria	Rank
Avoidance of residential areas	1 ↑
Level of public opposition	2 ↑
Minimization of environmental impacts	3 ↑
Avoidance of proximity to schools	4 ↔
Cost of obtaining land or easement	5 ↑
Ability to co-site with other facilities	6 ↔
Ownership of the land	7 ↔
Minimization of EMF exposure	8 ↔
Future secondary use of ROW	9 ↔

Note: Arrows indicate whether a majority of respondents stated that the importance of the criterion was increasing, decreasing, or not changing.

Land acquisition is a critical issue in routing a transmission line, and it is a great concern of energy companies. Invoking the power of eminent domain is one way to obtain land needed for a ROW. Two-thirds of respondents have power of eminent domain for intrastate land acquisition, and one-third for interstate land acquisition. These proportions are not predicted to change. Seventy-nine percent use eminent domain rarely, or only sometimes and 19% use it often or on nearly every new ROW project. Despite recent coverage in the popular press about a FERC role in condemnation, this group does not see the use of eminent domain as likely to change.

There are a number of ways companies compensate land owners to obtain a ROW: single compensation for easement (paying an owner one time for using land), outright purchase of land in fee, obtaining a permit to use land, and payment of an annual compensation for an easement. Ninety-eight percent of respondents stated that they use easements to obtain ROWs from landowners, 33% also purchase land outright (either the ROW or the entire parcel), and 13% obtain land use permits. Most easements involve one-time compensation; only 6% of respondents stated that they pay an annual compensation for an easement. This figure is notable because providing annual compensation, often called ROW rent, is a common practice of telecommunication companies seeking to site a cell tower. Some respondents mentioned this difference as the basis for quicker and easier siting of cell towers in comparison to obtaining a ROW for routing a transmission line; however, other possible reasons for a disparity between siting a single stationary telecommunications facility and routing a complex linear electrical facility should not be overlooked.

Companies offer a variety of benefits to landowners in order to acquire the ability to use a ROW. More than half (54%) offer construction of a road or other asset, others said they offer a low EMF configuration (40%), elimination of guy wires (38%), or a land swap, in which the company purchases land and exchanges it for the ROW (23%). Only one respondent mentioned offering underground placement of a line. Currently, individual property owners were reported by 52% of respondents to retain ownership of ROWs with an easement, and local utilities were reported to own ROWs by 40% of respondents. This is not expected to change in the next five years.

Technology

Three questions covered existing and new technologies relevant to routing transmission lines. A variety of ROW widths were reported to be used for single and double circuits and wood and steel construction. ROW width generally increases with voltage level of a line and for steel poles carrying the highest voltage lines.

When considering new technologies, respondents ranked the technical improvements that would make routing more acceptable from a political and social perspective, as seen in Table 2. More visually acceptable pole designs was ranked highest by a majority of respondents. This ranking is congruent with the respondents' perception of public concerns, in which visual impact was rated the number one concern.

Finally, respondents were asked to comment on the most significant changes that they envision in the responsibilities and processes for routing new transmission lines in the next five years. Mentioned most often were predictions about an increased role for RTOs, heightened public awareness and involvement in routing issues, an increase in regulations, more undergrounding of lines, and expansion of technology, such as GIS.

External factors

Public

Turning to the greatest public concerns about transmission lines, as perceived by respondents, the visual impact of the line and the effects of the line on property values (Mullins, 2003) were the top two concerns, with one or the other receiving the highest ranking by 60% of respondents (Table 3). Approximately 75% of the respondents view both of these concerns as increasing. EMF was the only issue that was seen by more than a handful of respondents as decreasing (25% of respondents). As mentioned previously, it is not known whether this finding may be explained by the lack of news coverage of EMF issues during the period of data collection, or by an actual decrease in level of importance over time relative to other concerns.

Communicating with the public is a critical way to address these concerns. The majority of respondents (83%) said that local utilities were primarily responsible for communicating with the public about proposed new or upgraded transmission lines and many (77%) predicted that this would not change. The most effective strategies that companies use for communicating with the general public were said to be holding meetings with landowners, holding open public informational meetings (one or the other of these was ranked highest by 65% of respondents), and making presentations to public groups. A majority of respondents predicted an increase in the importance of these three strategies (Vierima, 2001). Also viewed as increasing in importance was the use of an informational Web site. The remaining strategies were not predicted to change, although 6% of respondents said that use of bill inserts, videos, and media ads was decreasing in importance. These results are displayed in Table 4.

Table 2. Ranking of technical improvements

Technical Improvements	Rank
More visually acceptable pole designs	1
Easier sharing of ROWs with other utilities	2
Less objectionable vegetation management techniques	3
Improved use of ROWs as ecological habitats	4

Table 3. Ranking of public concerns

Public Concern	Rank
Visual impact	1 ↑
Property values	2 ↑
Compensation for land use	3 ↑
Equity/fairness of T-line route	4 ↑
Impacts of construction	5 ↑
EMF (electric and magnetic fields)	6 ↓
Need for the T-line	7 ↑
Corridor maintenance practices	8 ↔
Use of eminent domain	9 ↔
Stray voltage	10 ↔
Costs of the T-line	11 ↔

Note: Arrows indicate whether a majority of respondents stated that the importance of the criterion was increasing, decreasing, or not changing.

Table 4. Communication strategies

Communication Strategy	Rank
Meetings with landowners	1 ↑
Open public informational meetings	2 ↑
Presentations to public groups (e.g., civic orgs.)	3 ↑
Public workshops	4 ↔
Public focus/advisory groups	5 ↔
Brochures/bill inserts/newsletters	6 ↔
Public groups empowered to make decisions	7 ↔
Media information ads	8 ↔
Informational Web site	9 ↑
Videos	10 ↔

Note: Arrows indicate whether a majority of respondents stated that the importance of the criterion was increasing, decreasing, or not changing.

The most effective strategies employed by the public to oppose or influence routing are those that are the most difficult to counter. These were said to be primarily regulatory delays, pressure from local politicians, and lawsuits. Sixty percent of respondents chose one of these three criteria as their most important. All strategies were said to be increasing in use except violence, which was said to be not changing, and local moratoria on new transmission lines, which was evenly split between increasing and not changing.

Ninety-eight percent of respondents said that they countered these strategies by working more closely with the public. A majority also said they countered by maintaining greater local identity, offering additional compensation, and using eminent domain. Fifty-six percent of respondents said that landowners and tribes were more influential in transmission-line routing than the general public, and this is not predicted to change.

Regulatory

Many respondents (71%) stated that proposals for new transmission lines received a great deal of regulatory scrutiny and predicted that would continue to be the case in five years. Only 23% said that proposals for upgrading received a high level of regulatory scrutiny, and 21% said the same for proposals to rebuild transmission lines. A few respondents predicted that scrutiny for upgrading and rebuilding proposals would increase in five years.

Environmental assessments were reported by 75% of respondents to be conducted by the local utility and 65% expect this to be the case in five years. Twenty-one percent said that contractors currently carried out environmental assessments and 4% said this was done by an RTO. In five years 27% expect contractors will do this work and 8% expect that RTOs will do it.

Keeping in mind that respondents were answering questions in relation to their service territory, routing legislation at the state level was reported by 58% of respondents and at the local level by 33%, and not much change is expected. As to federal routing legislation, 33% expect it in five years but 27% do not. Respondents were divided in their opinion of how the process for routing multi-state transmission lines will change in the next five years: 42% predicted that federal power will begin to override state powers, and 40% predicted little change in the routing process, with state-by-state approval continuing to be granted across state lines.

From a political perspective, rankings showed that it is most difficult to route a line through residential areas, endangered species habitat, and areas near schools and day care centers. Lower in rank were tribal lands, wetlands, federal lands, recreational areas, and farmlands. This finding is compatible with the ranking of the routing criteria discussed earlier in which avoidance of residential areas was ranked most important and minimization of environmental impact was ranked third.

Fifty-two percent of respondents said the public utility commission was most likely to choose the final transmission-line route, and 31% said the local utility chooses. This responsibility was not expected to shift. On the other hand, the public utility commission was also ranked as one of the leading governmental bodies posing obstacles to routing or upgrading transmission lines, along with state and governmental agencies and local governmental bodies, and a majority indicated the latter two obstructions to be increasing. State legislatures and FERC were ranked lower in posing obstacles and this was not seen as changing in the near term.

Looking further into the future, 96% of respondents predicted that government would have more responsibility for routing transmission lines in the next five years. Seventy-seven percent said this would increase their workload, 90% said it would increase routing delays, 71% said it would increase routing controversy, and 31% said it would decrease certainty. On the other hand, 40% said it would increase certainty. Thus, respondents are divided on whether they think greater government involvement would increase or decrease certainty, but either way, there is strong agreement that it would increase workload, controversy, and delays.

CONCLUSIONS

Local utilities currently bear most of the responsibility for constructing, owning, and maintaining new transmission lines. Respondents do not expect this to change very much over the next five years. A few predicted that RTOs will take on more responsibility in the future, although as one stated, "Formation of independent transmission companies will require re-education of the public about serving interstate and regional needs, as opposed to local needs."

Respondents recognized the significance of public opposition and the importance of effective, on-going communication. They demonstrated a willingness to listen to the public by selecting the number one concern, more visually acceptable pole designs, as their highest priority for new technical improvements.

In agreement with recent policy proposals, respondents see some increased role of government as inevitable; in fact 96% think that government will have more responsibility for routing transmission lines in the future. But contrary to the intent of the proposals, a majority said it would increase controversy and delay routing. More than three-fourths of respondents said they believe such action would also add to their workload. In the end, whether increasing the role of FERC in transmission-line routing will streamline the process or exacerbate delays is open for speculation. Either way, ROW practitioners are in agreement—the most contentious issues are local ones, and the most effective strategy is education through improved communication.

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REFERENCES

Berenson A. 2003. Forget deregulation. It's the wires stupid. New York Times–Week in Review Aug 24: p 3.

Coyne J. and P. Hartshorne. 2003. Winners and losers in restructuring: assessing electric and gas company financial performance. Cambridge, MA: Lexecon Inc.

Mullins P. 2003. Transmission lines and property values: state of the science. Palo Alto, CA: Electric Power Research Institute. Dec 1005546.

Stone B. 2003. How to fix the grid. Newsweek Aug 25: p 38.

Vierima T. 2001. Communicating with the public about rights-of-way: a practitioner's guide. Palo Alto, CA: Electric Power Research Institute. Sep 1005189.

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His research activities focus on water quality criteria development and assessment; model development to assess metal toxicity to fish to reduce compliance costs; transport and fate of mercury in the aquatic environment and the further development of the Dynamic Mercury Cycling Model; development of integrated vegetation management to reduce vegetation management costs and outages; development of remote sensing technology for more real-time assessment of transmission rights-of-way conditions; and development of information to reduce interruptions and outages on distribution systems. He also developed and manages an innovative research program on the use of constructed wetlands and other passive technologies for the treatment of wastewater.

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An Environmental Strategic Siting Study and Public Process for a 500 kV Transmission Line Project in the Desert Southwest

Dan Hawkins, Ray Hedrick, Kenda Pollio, and Doni Lynn Harris

The Salt River Project Agricultural Improvement and Power District (SRP), with participation of other utilities, has proposed two separate Projects involving the siting of electrical utility components; the Palo Verde to Pinal West (PV-PW) Project, which includes two parallel single circuit 500 kilovolt (kV) transmission lines, and a 500/345/69 kV substation and the Pinal West to Southeast Valley/Browning (PW-SEV/Browning) Project, which is a single circuit 500 kV line, portions of which would be double circuit 500/230 kV, and up to four associated substations. These Projects are located in central Arizona. The cumulative study area encompasses over 2000 square miles and includes municipalities with some of the highest growth rates in the U.S. As part of the overall process, an extensive environmental siting study and Public Process was implemented in three distinct phases, as follows:

Phase I – Demonstration of Need and Benefit;

Phase II – Opportunities, Sensitivities, and Avoidance Areas Environmental Criteria Refinement and Analysis; and

Phase III – Routing and Alternatives Comparative Analysis.

Each phase focused on engaging the public and other interested stakeholders in the study area to assist in strategic planning, the identification and categorization of the environmental siting criteria, and the analysis of potential routing alternatives as associated with the overall siting study. An interactive geographic information system (GIS) database was also utilized in the Public Process. This paper will present the strategic approach and methodology of successfully siting and implementing a high voltage transmission line Project in a major growth area with diverse and significant continuous changes in land use and jurisdictional boundaries.

Keywords: Environmental siting, transmission line, GIS, ROW

STRATEGIC STRATEGIES FOR SITING AND PUBLIC PROCESS

The objective of the Public Process for a typical transmission line or substation siting project would be to develop an informed and visible understanding of the project to the majority of the public and build acceptance and support for the project where ever possible. While the Public Process for a project would typically be based on these objectives, it is important to understand that the approval of such projects would also normally require the involvement, understanding, and support of elected officials, decision-makers, agency personnel, and special interest groups. Consequently, implementing an integrated Public Process that proactively manages actual and perceived roadblocks (e.g., public perception, legal issues, political agendas and environmental and permitting constraints) is essential to successfully site and permit a project.

An integrated Public Process that provides consistent and continuing information about the project and process so the public becomes fully aware of the why and how of a project is critical to successful permitting. In this way, even if they disagree with the outcome, they understand how the decision was reached.

The following paper presents the Public Process that was undertaken for siting two 500 kV transmission line

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projects and has resulted in the successful permitting of the first Project, which consists of over 50 miles of two parallel single circuit 500 kV transmission lines and a substation in Arizona. The Public Process for the second Project (which consists of single circuit 500 kV lines, double circuit 500–230 kV line and four substations) has been completed, but the permitting is still in process.

PROJECT OVERVIEW

The Salt River Project Agricultural Improvement and Power District (SRP), as the Project Manager on behalf of and in participation with Arizona Public Service Company (APS), Tucson Electric Power Company (TEP), and Santa Cruz Water and Power Districts Association (SCWPDA), which is comprised of the Electrical Districts (EDs) ED3, ED4, and ED2, the Maricopa-Stanfield Irrigation and Drainage District (MSIDD), and the Central Arizona Irrigation and Drainage District (CAIDD); has proposed two separate Projects involving the siting of electrical utility in a region which is one of the fastest growing areas in the U.S. The Projects include the Palo Verde to Pinal West (PV-PW) Project, which includes two parallel single circuit 500 kilovolt (kV) transmission lines and a 500/345/69 kV substation and the Pinal West to Southeast Valley/Browning (PW-SEV/Browning) Project, which is a single circuit 500 kV line, portions of which would be double circuit 500/230 kV, and up to four associated substations. These Projects are located in central Arizona. The cumulative study area encompasses over 2000 square miles and includes traversing 10 municipal jurisdictions.

Specifically, the PV-PW Project was comprised of two single circuit 500 kV transmission lines from the Palo Verde hub in western Arizona to a new substation to be located in western Pinal County, Arizona, named the proposed PW Substation, and an interconnection with the TEP Westwing – South 345 kV transmission line (Westwing – South line). The Pinal West to Southeast Valley/Browning Project (PW – SEV/Browning) is the second project element, which includes single circuit 500 kV and 500–230 kV components from the proposed PW Substation to terminate at a new substation, Southeast Valley (SEV), to be located in northeastern Pinal County, with a continuing 500–230 kV line extending to the existing Browning Substation in Maricopa County, Arizona. The total length of the two Projects would be approximately 100–150 miles in length.

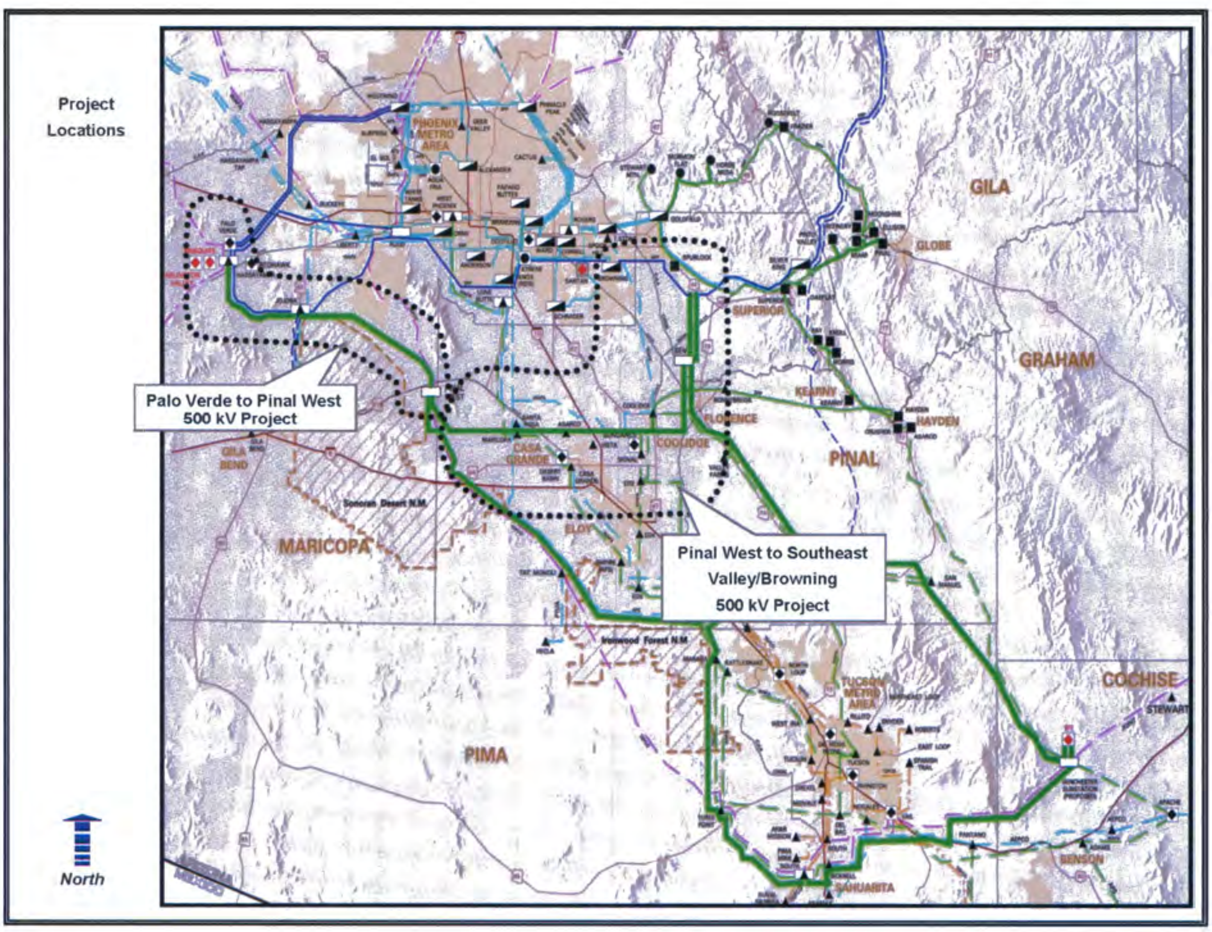

Fig. 1. Project locations.

While the two elements were independent of one another, the Project proponents originally believed a single siting process would better inform the public of the development of electrical transmission facilities in the region, be more time efficient, and more cost effective. A timing issue arose, as the first phase the PV-PW Project required an earlier in-service date and necessitated the development of two separate State permitting processes. The Public Process, however, for both the PV-PW Project and PW-SEV/Browning Project was conducted jointly even though they were permitted separately.

The Projects were conceived, in part, as a result of a regional transmission study named the Central Arizona Transmission System (CATS) study. The CATS study was the direct result of a January 2000 Arizona Corporation Commission (ACC) Transmission Line and Power Plant Siting Committee workshop on transmission and generation issues. The study was a collaborative effort by over twenty public and private utility and energy companies in Arizona with the participation of ACC staff. The purpose of the study was to examine ways to increase transmission capacity and reliability throughout the State, specifically in central Arizona. The CATS study was an effort to conduct comprehensive system planning by assessing the need for regional electrical transmission infrastructure. A conclusion of the CATS Phase I effort was the identification of a 500 kV transmission system blue print for central Arizona, of which the PV-PW and PW-SEV/Browning Projects were identified as an element.

Load growth throughout the State of Arizona, along with the use of the transmission system by merchant generators brought about by wholesale open access, has been taxing existing transmission facilities. The existing electrical system was developed in a time when transmission lines were associated with specific generation projects. It was not envisioned to be a robust system providing unencumbered access to markets via the "electric grid." The Project was a response to this load growth by providing an additional path to move energy from new generation facilities near the Palo Verde hub to regional load areas, as well as to alleviate transmission constraints.

The Projects address this increased demand for energy delivery in central Arizona by improving transmission capacity, reliability, and overall system support. The Project will also increase reliability by providing a parallel path for portions of the existing transmission system. When interconnected with the local system, the Projects will provide greater voltage support, which would in turn, relieve the loading on the existing, lower voltage system currently serving this area. The Project will improve reliability and performance of the Palo Verde hub by providing additional outlet capability and redundancy to the existing Palo Verde East transmission path.

The Project will enable the movement of energy from the Palo Verde hub (an energy market), to central Arizona. The Project will provide additional transmission opportunities to support future growth in Maricopa, Pinal, and Pima Counties (the central Interstate 10 Highway corridor) and provide increased reliability to the central Arizona power grid, as a whole, in accordance with the CATS study objective. The Project would also create another transmission path from the Palo Verde Hub allowing easier access to competitive markets.

Project construction for the first line of the PV-PW Project is anticipated to begin in 2005 and continue for approximately 12 to 18 months to meet an in-service date in 2006. The PW-SEV/Browning Project currently is being permitting and proposed to be in-service in segments from 2007–2011.

PLANNING AND SITING PROCESS AND METHODS OF COMMUNICATION

The Project initiated a Public Process with a goal of not only presenting information to the public about the Project, but bringing the public along through the process in order to inform the public, obtain comments and input on the siting process and to validate information. More important, the process enabled the public to be a part of the siting process, to understand how and why projects are sited and the methods for siting and locating linear projects. The ultimate goal is not for the public to agree where the Project should be sited, but instead understand that there is a definitive method, criteria and siting process that determines the location. The goal was not to obtain consensus or have universal support, but rather have the public and stakeholders understand that the Project is needed and that there was an analytical criteria guided process for developing routing alternatives and siting the Project.

Public process programs

To achieve this, the Project developed a Public Process that incorporates three public process programs, as follows:

Public Involvement (PI);
Public Relations (PR); and
Public Affairs (PA).

The Project Team understood that each one of these programs will be critical in the process and has developed a plan for each one of the Project phases.

Public involvement

Public involvement is an interactive process targeted at developing and distributing select messages and working collaboratively with the community leaders, decision-makers, stakeholders, and the public at large through scheduled meetings, workshops and open houses. This program is important because it informs all stakeholders and sets the stage for the public hearings associated with permitting procedures required by federal, state, and local jurisdictions.

Public relations
The public relations program involves primarily one-way communication with stakeholders (business owners, landowners, political officials, press/media representatives, opinion leaders, community leaders, registered voters, and the general public) in the Project area.

Public affairs
A strategic public affairs program is also critically important to the successful outcome of a project. Public affairs in the context of this Project deal with the sophisticated audiences of policy makers, gatekeepers, opinion leaders, and elected officials. Without their support (or at least neutrality) it would be difficult to succeed.

Key constituencies must be addressed with full understanding that it is they who are in a position to exercise power over events by virtue of elected office held, influence exercised, or resources expended. Messages to these audiences are in-depth, and communications with them are often delivered one-on-one. The style of relations with these key groups is one of respect exemplified by thorough preparation and "ahead of the crowd" timing. The messenger can be as important as the message itself. A well-implemented program will do more to help the Project avoid time-consuming and expensive obstacles than almost any other component of the Public Process.

Public process phases
As part of the overall planning and siting process for the Project, the Project Team conducted extensive Public Process phases intended to provide information regarding the Project and solicit comments from the public. The Project Team placed special emphasis on receiving comments from community leaders, elected officials, and other interested parties. The public process was conducted in three phases as follows:

Phase I – Project Need and Benefits;
Phase II – Opportunities, Sensitivities, and Avoidance Areas; and
Phase III – Routing and Alternatives.

During each phase of the Public Process, there have been several venues and ways for members of the public to become informed and participate in the process. They have included the following:

- Project Announcements and Newsletters (mailed to all zip codes in the Project study area);
- Community Representative Forum (CRF);
- Public Open Houses;
- Public Information Meetings;
- Project Website (the Project maintains a Project website, www.azpower.org, which includes figures, schedules, and general Project information);
- Presentations at Community Meetings;
- Toll-free Telephone Project Information Line;
- Public Notices, Flyers, and Posters; and
- Pre-addressed Comment Forms.

Phase I – Project need and benefit
The purpose of Phase I was to introduce the Project to the public. The Project Team presented information explaining the need and benefit to the region. As previously discussed the Project was a result of the CATS study and an effort to provide transmission into the growing load center. The goal of this phase of the process was to only discuss the overall purpose and need prior to the alternatives being analyzed or presented.

Phase II – Opportunities, sensitivities, and avoidance areas
The purpose of Phase II was to seek public input to identify and categorize into qualitative rankings (high, medium, and low) opportunities and sensitivities of the environmental siting criteria. Phase II input included written and verbal comments, but most notably the inclusion of comments into an interactive Geographic Information System (GIS) database. Public participants were provided the opportunity to validate data and view locations of interest projected in large-screen format from a GIS.

Initially, the siting criteria applicable to this specific Project were developed to define the constraints and to identify the opportunities for routing a transmission line and locating substations. Using resource data and mapping techniques, the Project prepared an opportunity and constraints analysis to map and illustrate sensitive environmental areas and highlight routing opportunities.

Constraints
Routing constraints are areas containing resources that could impact the development of a project. Often, constraints are subdivided in two categories, as follows:

Avoidance Areas
These are areas where siting the line would be extremely difficult or nearly impossible for one or more reasons (economics, politics, permitting timeframes, construction difficulty, etc.). These were excluded as potential areas through which the Project could be located. They are mapped in red to stand out in the Project area.

Sensitive Areas
These are areas where siting the line would be possible but specific issues or conditions exist that could make developing the Project more difficult, more time-consuming, or costly. They were mapped in yellow to indicate the need for caution.

Opportunities
Generally, for transmission Projects, siting opportunities are existing linear features that could be paralleled by the proposed Project. This makes it unnecessary to introduce a new linear feature into the land use patterns of an area, and is generally consistent with

Table 1. Representative standard opportunities and constraints for siting high voltage transmission lines

Opportunities
Existing utility rights-of-way (e.g., electric transmission lines, pipelines).
Existing railroads.
Existing highways, roads.
Existing canals.
Existing waterway crossing points, bridges.
Section or property lines.
Sensitive Areas
Existing / planned residential areas.
Prime farmlands and areas of intensive agricultural activity, and center-pivot irrigation systems where the Project would interfere with irrigation.
Designated or registered national historic districts, memorial parks, wildlife areas, wildlife refuges, game management areas, forest, and forest management areas.
Designated or registered state or national parks.
County parks and recreational areas, municipal parks, and parks owned or administered by other governmental subdivisions.
Buried mineral resources.
Towns and cities.
Scenic areas, including scenic travel routes, and crossing hills at crests.
Airport approach flight paths, and VORTAC tower sites.
Federal-, state-, and agency-owned properties.
National wild and scenic rivers.
Areas that are geologically unstable or highly erosive.
Waterfowl nesting or rearing areas.
Open water expanses of more than 1000 feet.
Threatened and endangered species nesting or critical habitat areas.
National landmarks, national monuments, nature conservancy preserves, state scientific and natural areas, state and national wilderness areas.
Avoidance Areas
Indian Lands.
National Register of Historic Places sites.
Airports.
Placement of a new transmission line over existing residence or other occupied buildings.

the land use direction of federal, state, and local land management and siting authorities. Potential routing opportunities in the Project area were identified and mapped as green corridors to indicate their potential as routing possibilities.

Table 1 lists some general standard constraints and opportunities for siting transmission lines. The resource constraints identified in the Table 1 were evaluated for their presence in the Project area and their relative sensitivity to the construction, operation, and maintenance of a transmission line. Using the collected data, as well as information gathered during initial agency contacts, the list of environmental opportunities and constraints was refined by the Project Team.

Phase III – Routing and alternatives

Once the opportunity and constraint areas were identified, the Project Team developed and compared potentially viable alternatives. Quantifiable information was presented for each potential alternative to identify the comparative impacts associated with each. During Phase III, potential routing alternatives were presented and discussed.

Venues for Public Involvement

The public perception associated with transmission line and substation siting and permitting projects often have as large an impact on the ultimate siting decisions as any other factor associated with the process. Therefore, effective public involvement was an important part of the siting process for this Project. Public involvement was facilitated through a number of different processes and activities.

Community Representative Forum

A Community Representative Forum (CRF) was conducted during each phase of the Public Process. The purpose of the CRF was to encourage the participation of community leaders during the planning and siting of the Project. The CRF was comprised of a group of interested municipal entities, public officials, and other interested parties. The Project did not invite specific individuals, but instead invited organizations to nominate representatives to participate in each phase. The following list includes the organizations invited to participate in the CRF:

Chambers of Commerce

Apache Junction Chamber of Commerce
Arizona Chamber of Commerce
Arizona City Chamber of Commerce
Casa Grande Chamber of Commerce
Coolidge Chamber of Commerce

Florence Chamber of Commerce
Eloy Chamber of Commerce
Mesa Chamber of Commerce
Queen Creek Chamber of Commerce
Southwest Valley Chamber of Commerce

City Managers
City of Apache Junction City Manager
City of Casa Grande City Manager
City of Coolidge City Manager
City of Eloy City Manager
Town of Florence City Manager
City of Goodyear City Manager
City of Mesa City Manager
Town of Queen Creek City Manager

Economic Development Organizations
Greater Casa Grande Valley Economic Development Foundation
East Valley Chamber Alliance
East Valley Partnership
WESTMARC

Elected Officials
Pinal County Board of Supervisors
Maricopa County Board of Supervisors
City of Apache Junction Mayor/ City Council
City of Casa Grande Mayor/ City Council
City of Coolidge Mayor/ City Council
City of Eloy Mayor/ City Council
Town of Florence Mayor/ City Council
City of Goodyear Mayor/ City Council
City of Mesa Mayor/ City Council
Town of Queen Creek Mayor/ City Council

Environmental Organizations
Sierra Club
Audubon Society
Nature Conservancy

Indian Communities
Ak Chin Indian Community
Gila River Indian Community
Tohono O'odham Nation

Planning Organizations
Pinal County Planning
Maricopa County Planning
City of Apache Junction Planning
City of Casa Grande Planning
City of Coolidge Planning
City of Eloy Planning
Town of Florence Planning
City of Goodyear Planning
Town of Queen Creek Planning

School Districts
Apache Junction Unified District
Arlington Elementary District
Buckeye Union High School District
Casa Grande Elementary District
Central Arizona College
Coolidge Unified District
Eloy Elementary District
Florence Unified School District
Maricopa Unified School District
Mesa Unified District
Mobile Elementary District
Palo Verde Elementary School District
Picacho Elementary District
Queen Creek Unified District
Sacaton Elementary District
Saddle Mountain Unified School District
Santa Cruz Valley Union High School District
Stanfield Elementary District
Superior Unified District
Toltec Elementary District

The CRF provided each representative a unique opportunity to understand the Project, its purpose, need, and schedule. It also provided representatives the ability to participate in the identification and categorization of opportunities and sensitivities, based on the environmental siting criteria that best represent community values and perceptions. In addition, the members of the CRF were educated on the Project so they may be able to respond to members of the public that may contact them with questions or concerns regarding the Project. The CRF meetings were also conducted prior to each Open House series in order for the community leaders to understand what would be presented to the public. In a number of cases, this allowed these leaders to participate in the Open House series.

Open Houses
In addition to the CRF, the Project conducted a series of Open Houses throughout the Project study area for each phase of the Public Process. Open Houses were held to inform the public and provide an opportunity for questions and comments on the Project. The Project Team notified individuals of the Open Houses by mailing out notices to all individuals that had an address within zip codes inside the Project study area. This same extensive mailing was conducted three times for each Open House series. In addition to the mailed notices, announcements of the Open Houses were also posted at public gathering places. The mailed notices and announcements were provided in both English and Spanish and a Spanish-speaking member of the Project Team was present at all Open Houses. The Project held approximately 5 Open Houses in each Public Process Phase previously identified.

Using GIS as a tool in the public and siting process

The development of the GIS geospatial database allowed each audience and process component to be interconnected via one medium, real-time. Initially, spatial data, or data coverages, were collected from a number of sources, most specifically affected jurisdictions and interested stakeholders. This encouraged the engagement of these entities and individuals very early in the process. Recent aerial photography was the underlying element of the geospatial database.

For each phase of the Public Process, interactive GIS was used to validate data included within the geospatial database, capture comments and public input, generate site-specific maps linking comments and input to specific parcels, and identify spatial relationships between subjects of interest. Participants of the Public Process are always your best and worst critic regarding maps and information distributed. Because a number of data sources were used (and often accuracy questioned), public participation was utilized as a means of quality control in validating data. Capturing general comments and public input was done interactively by linking comments to a precise point, area, or linear feature and attributing that element with the specific comment. Entering comment attributes real-time, as the GIS was projected to a large screen, ensured that the comment was received and integrated into the process. Generating site-specific maps allowed public participants the opportunity to leave the public venue with something in-hand that tied the regional 'big picture' specifically back to them and their property. Often times, specific concerns or issues are alleviated if public participants can simply locate features on the map or on-screen as was used in these venues. Utilizing interactive GIS offered public participants some ownership in the Project. They specifically assisted in the development of the geospatial database, which was ultimately used to analyze and determine potential routing alternatives. Most significantly, the general functionality of interactive GIS, including panning, zooming, measuring distances real-time, and selecting data coverages to be displayed, etc. was useful in the siting study. This is essential in establishing proximity and spatial relationships between subjects of interest, such as existing facilities and schools.

The siting study required the comprehensive comparative analysis of all potential routing alternatives using a tiered approach facilitated by the GIS. This analysis included not only the examination of the environmental siting criteria, but also incorporated comments and input received via the public participation process. Routing alternatives were separated into 'families of alternatives' based on general geographic area and compared among each other within only that family. Those alternatives within each family strongest in opportunity and having minimal impact to sensitivities were then compared to alternatives in other families. The final tier of comparative analysis involved the development of the proposed alignment or route.

Another component of the geospatial database was the archiving of data and information. This data and information includes everything associated with the siting study and Public Process, in addition to specific components of the federal compliance and state environmental permitting processes. For example, areas of limited concern identified in a US Fish and Wildlife Service letter of concurrence were archived in the geospatial database by linking the letter itself to a polygonal habitat coverage. Interactive GIS was used again in the public hearings associated with the state environmental permitting process. This demonstrated the same functionality as used in the Public Process, however, more so in that the accumulation of all analysis and integration of process components were readily available.

Using GIS as a tool in the Public and Siting Process was critical to the success of the PV-PW Project. The development of the geospatial database allowed the interconnection of each audience and process component via one medium, real-time. It promulgated public participation and a sense of ownership in the Project. It also facilitated the tiered approach necessary to complete the comprehensive comparative analysis of all potential routing alternatives. And finally, the use of interactive GIS in the public hearings associated with the state environmental permitting process was a precedent. Archived data and information, attributed comment fields, photos of existing residences or properties linked to comment forms and the validation of data are all functions of real-time, interactive GIS.

Interactive contact database

The interactive contact database provided a record of contact and correspondence. Hosted online, the information included in the contact database was readily available to the Project Team. The contact database allowed the input of contact information for interested members of the public, stakeholders, and affected jurisdictions and the attachment of any specific items of correspondence such as comment forms, maps, letters, etc. This tool was extremely beneficial to the Project in that any member of the Project Team had the information readily available to them to respond to any information request. The contact database was also in a format that could be easily downloaded and sorted to assess such things as majority concerns, etc. As the Project transitioned into the right-of-way acquisition process, the contact database and inclusive information was still readily available. The contact database had established a tracking mechanism of individual property owners. The interactive contact database and the interactive GIS were directly correlated and together provided a firm and archived foundation to Project development.

Project success

While the Public Process may have appeared as a long and engaging process, the ultimate goal of the Project's federal and state permitting process was a success. The PV-PW Project completed the State of Arizona Certificate of Environmental Compatibility process with a unanimous vote in favor of the Project from the Arizona Transmission Line and Power Plant Siting Committee (Siting Committee) and the ACC. The Siting Committee held several days of hearings and along with the ACC's brief hearing, concluded with a unanimous vote by both bodies in favor of the Project. The public was invited to speak at each day of the hearings and a special evening public comment session was held. While some members of the public did in fact speak about preference to a specific alternative versus the preferred route, not one member of the public identified that they had never heard about the Project and instead voiced an opinion on a specific route preference. It was clear the ultimate goal of the Project was achieved. While no one testified to wanting the Project in their backyard, it was clearly acknowledged that the public was informed of the Project, the Project was needed, a process was undertaken and they were given the opportunity to state a preference to a route.

BIOGRAPHICAL SKETCHES

Dan Hawkins

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Mr. Hawkins has over 30 years of experience within the electric utility industry in transmission line planning, design, construction, maintenance and siting. Mr. Hawkins is the Project Manager for the Palo Verde – Pinal West 500 kV and Pinal West – Southeast Valley/Browning Transmission Line Projects. He was also recently the Project Engineer for the Schrader and Browning Transmission Line Projects. In addition to Project Management of siting, design and construction of new electrical transmission projects, Dan's responsibilities have also included Project Management of a major visibility study and relocation of electrical facilities that conflicted with freeway expansion plans. Mr. Hawkins earned a Bachelor of Science Degree in Electrical Engineering from Arizona State University and is married with seven sons.

Ray Hedrick

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Mr. Hedrick has over 25 years of Environmental Management experience working within the electric utility industry, serving as a consultant and a regulator and managing the responsibilities of siting new electrical and generation projects. He is the SRP Environmental Project Manager for the Palo Verde – Pinal West 500 kV and Pinal West – Southeast Valley/Browning transmission line Projects and was recently the Project Manager for the National Environmental Policy Act (NEPA) process for two power plant projects totaling 1,000 MW and a 37 mile natural gas pipeline project. Mr. Hedrick earned Bachelor of Science and Master of Science Degrees in Wildlife Management from Oklahoma State University.

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Ms. Pollio is a Senior Environmental Planner and Project Manager specializing in linear corridor and right-of-way assessment, siting, acquisition, permitting, easements, and government compliance. She has conducted environmental assessments, public participation programming, land use planning and zoning, and socioeconomic planning. She has also obtained federal, state, and local approvals for a variety of projects. She is familiar with local government zoning processes, state regulatory requirements throughout the United States, and federal compliance requirements. Ms. Pollio has extensive expertise siting and permitting linear transmission line projects. She has managed and provided planning support for electric transmission line siting, transmission upgrades and rebuilds, as well as substation siting and permitting. She has coordinated permitting efforts with federal, state, and local agencies for transmission lines ranging from 69 kV to 500 kV. Ms. Pollio has also conducted impact analyses and has prepared Environmental Assessments (EAs) and Environmental Impact Statements (EISs) for a variety of federal agencies or applicants in compliance with the National Environmental Policy Act (NEPA). These agencies include the USDA Forest Service, the National Park Service, the Bureau of Land Management, Western Area Power Administration, and the Federal Highway Administration. For these projects, Ms. Pollio has served in the capacities of technical lead, technical writer, editor, project coordinator, and Project Manager.

Doni Lynn Harris

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Ms. Doni Lynn Harris is a Project Scientist and Assistant Project Manager specializing in planning, environmental compliance, permitting, geographical information systems (GIS), linear corridor and right-of-way assessment, siting, and acquisition. She has assisted in environmental assessments and impact studies as associated with the National Environmental Policy Act (NEPA), state and local permitting processes, public participation programs, impacts analysis studies and risk assessments, and feasibility studies. Ms. Harris has provided management and planning support for siting and permitting electrical transmission line projects involving new construction, upgrades and rebuilds, and associated substations or generating facilities. She has assisted in the coordination of right-of-way acquisition, easements, and permitting efforts with federal, state, and local entities for transmission lines ranging from 69 kV to 500 kV.

EPRI–GTC Tailored Collaboration Project: A Standardized Methodology for Siting Overhead Electric Transmission Lines

Steven French, Gayle Houston, Christy Johnson, and Jesse Glasgow

A team sponsored by the Electric Power Research Institute (EPRI) and Georgia Transmission Corporation (GTC) conducted a two-year study of transmission line siting and produced a new approach for making siting decisions more quantifiable, consistent and defensible. Using GTC's existing transmission line siting process, the study incorporated GIS technology, statistical evaluation methods and stakeholder collaboration to produce a new siting methodology. The tools, techniques and procedures developed by the team were demonstrated through practical application on construction projects. An EPRI-GTC Overhead Electric Transmission Line Siting Methodology report will be published soon that describes how the team:

1. Developed a new GIS siting model and management procedures for producing more objective, quantifiable and consistent siting decisions;
2. Obtained more than 400 stakeholders' critical reviews and achieved consensus on the ranking of geographic, land use, environmental, engineering and other GIS database features, as well as the weighting of data layers;
3. Ensured the process conforms to environmental laws; and
4. Revised Georgia Transmission's existing overhead transmission line siting practice.

The team produced a standardized process that other utilities can use to improve the way transmission lines are sited.

Keywords: Electric, transmission, siting, power lines, GIS, ROW

INTRODUCTION

The Electric Power Research Institute (EPRI) and Georgia Transmission Corporation (GTC) entered into a Tailored Collaboration Project to provide GTC with an Overhead Electric Transmission Line Siting Methodology that is consistent, integrated, and defensible. The project demonstrates the use of advanced geographic information system (GIS) techniques based on Delphi and Analytical Hierarchy processes as well as innovative public participation efforts.

In the United States, increasing population and continuing growth in demand for electricity will require the construction of thousands of miles of new transmission lines in the next decade. The routing of overhead electric transmission lines, however, has become increasingly difficult because citizens groups are more vocal and environmental regulations are more stringent. To address this issue, EPRI and GTC developed a Standardized Overhead Electric Transmission Line Siting Methodology. The methodology has four major steps, as follows:

1. Identification of Macro Corridors;
2. Generation of Alternative Corridors within the Macro Corridors;
3. Delineation of Alternative Routes within the Alternative Corridors; and
4. Evaluation and Selection of the Preferred Route.

The overall approach can be thought of as a funnel where more data with increased accuracy is brought to bear as the potential location for a potential route is narrowed down through successive steps in the analysis. Relatively coarse data on several key factors are used to define a set of Macro Corridors. Within these areas finer-grained data are collected on additional factors and used to create a set of Alternative Corridors and then define Alternative Routes within them. Even

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more detailed data, including field surveys, are collected along these actual routes. These data are used to select a single Preferred Route.

The EPRI-GTC Overhead Electric Transmission Line Siting Methodology is based on land suitability analysis techniques that were developed by Ian McHarg in the early 1970's. This methodology combines multiple data layers into a comprehensive surface that identifies areas of opportunity and constraint. The McHarg process is widely used for siting a variety of facilities, including: shopping centers, subdivisions, and linear utility corridors. Contemporary applications, however, extend the procedures by employing new technologies such as GIS, visual simulation, and Global Positioning Systems (GPS).

This methodology relies on a Geographic Information System (GIS) to manage and model all of the data required to locate a transmission line. Because the methodology is implemented using GIS, users must be explicit about what data are to be considered and how the data will be analyzed to produce a preferred route. The structured nature of the methodology helps ensure that it will be consistently applied across projects, locations, and by different siting teams. To be successful and defensible, it is important that all information and assumptions used in choosing a Preferred Route and avoiding less suitable alternatives are available and that the decision is well documented and reproducible.

As in most GIS applications, the data are organized into separate layers that represent different factors that are relevant to transmission line siting (e.g., slope, wetlands, housing density). To support the suitability analysis all of the data were represented in a grid structure. The size of the grid becomes smaller in succeeding phases of the analysis. Each data layer is composed of a number of categorical values or Features. For example, the slope layer is divided into three Features that describe the slope at that location: less than 10%, 10–25% or greater than 25%. Each data layer covers the entire study area, so that each grid cell has a value for each data layers.

GTC intends to use the method developed and tested during this project to carefully and consistently examine all phases of overhead transmission line siting. This methodology gives GTC a process that is scientifically rigorous, peer reviewed and tested on multiple overhead electric transmission line projects. As a result, GTC is better prepared to explain, justify and defend its transmission line siting decisions to a broad range of stakeholders, including: legislative, regulatory, and, other public and non-governmental entities.

In addition, this process standardizes GTC's core routing and siting business practice. It provides opportunities for GTC to evaluate a range of alternative routes that represent both corporate values and community concerns. Standardization fosters sound siting decisions by developing decision and selection criteria that are more objective and uniform. The method allows the effects of each alternative route to be examined and compared more consistently and objectively. In addition, standardization of the process provides consistency in data acquisition and use. This in turn maintains a level of accuracy that helps the company identify, analyze and select routes that are more economically acceptable, by avoiding locations that are difficult to permit or mitigate. Thus, under the GTC methodology, the preferred route produced by this process is more defensible because it is based on a rationale that links decisions with consequences.

STAKEHOLDER INVOLVEMENT

A number of groups and agencies have an interest in the siting of electric power transmission lines. To incorporate these interests in the structure of the siting methodology this project solicited input from stakeholders representing federal and state regulatory agencies, environmental and land conservation organizations, community homeowner groups, as well as siting professionals from other electric utility companies. These stakeholders helped to identify what types of data should be considered and the relative importance of different types of data in the siting process. The inclusion of stakeholders in the development of the methodology is fairly unique among electric utilities.

The research team developed a comprehensive list of potential stakeholders organizations. Representatives from each organization were invited to participate in five multi-day workshops. Special attention was given to involving representatives of homeowner and citizen groups. Every effort was made to represent all viewpoints in the stakeholder workshops.

Stakeholders were first given an overview of the entire siting methodology. They were then asked to review the data layers that the research team had identified as relevant to the Alternative Corridor Generation process. The stakeholders suggested that several data layers be dropped and that more detailed land use data be included.

A Delphi Process was used to rank the suitability of each Feature in the layers used for Alternative Corridor Generation on a scale of 1 to 9 with 1 indicating most suitable and 9 least suitable. For example, a participant might rank wetlands as an 8 indicating this location is very unsuitable for a transmission line. Each stakeholder provided their rankings and then the whole group was shown the maximum, minimum ranking as well as the mean, median and standard deviation for each Feature. The group then discussed those Features where there was significant variation in the rankings. This process was repeated through multiple rounds. A reasonable level of consensus was usually achieved after two or three rounds.

The Analytic Hierarchical Process (AHP) is widely used to choose among a discrete set of alternatives. Stakeholders used AHP to determine the relative importance of each Data Layer using pairwise combinations. For example, they would be asked to say how much more important steep slopes are than wetlands (or visa versa) in siting transmission lines. The result of this process produced a set weights that are used to combine multiple data layers.

Transmission line siting professionals have indicated that the involvement of external stakeholders throughout the development of the siting methodology was a unique approach. This approach is a significant departure from most other transmission line siting methodologies because it integrated stakeholder input into the development of the methodology and produced standardized feature values and layer weighting that will be applied to individual siting projects.

OVERVIEW OF SITING METHODOLOGY

Before the siting process begins the two endpoints of a proposed route must be determined by Electric Systems Planning. The siting methodology is designed to produce a route that connects two or more points. If the Electric Systems Planning cannot define the endpoints that need to be connected, the siting methodology will not perform properly.

In the first step of the process, Macro Corridors are identified through a generalized suitability analysis that operates on a limited set of off-the-shelf data. The purpose of this phase is to quickly eliminate from study those areas that are not suitable for a transmission line. The outside limits of the Macro Corridors become the boundaries of the project study area.

In the next step, more specific Alternative Corridors are developed within the Macro Corridors. During this step, aerial photography composed of 1-foot grid cells is acquired and digital orthophotography is produced. More detailed digital data are collected on environmental factors, existing development and cultural resources. This more detailed data are used to identify four distinct types of alternative corridors that emphasize different perspectives on transmission line siting.

In the third step, the siting team identifies a set of Alternative Routes within the Alternative Corridors. Each route is then scored using a standard set of evaluation criteria and compared.

Finally, the preferred route is selected from the alternative routes based on this comparison.

Step 1: Macro Corridor Generation

The Macro Corridor Generation process relies on the availability of inexpensive and/or free off-the-shelf digital data. This is intended to eliminate the need for unnecessary data collection and data processing. The GIS analysis identifies corridors that minimize impacts to the built and natural environment. The Macro Corridors eliminate those areas where there is no viable option for building a transmission line. The Macro Corridors define the area where orthophotography and other detailed data collection and analysis will occur in Phase 2.

Macro Corridor Generation is designed to use readily available, existing digital data layers. This allows quick identification of the project area. These existing datasets include the following:

- Land cover derived from Landsat satellite imagery;
- Digital Elevation Models (DEMs);
- Existing roads from the Geographic Data Technologies (GDT); and
- Existing electric transmission lines from the Georgia Integrated Transmission System (ITS) dataset.

The project team used its professional judgment to rank the suitability of these features for cross-country, road parallel, and existing transmission line rebuild/parallel routes.

In addition to these digital datasets, data are also acquired about areas where routes are prohibited either by physical barriers, administrative regulations, or where there are likely to be significant permitting delays. These "Avoidance Areas" include National Register of Historic Places (NRHP), listed historic structures or districts, NRHP listed archeological sites or districts, airports, EPA Superfund sites, military bases, National and State Parks, non-spannable water bodies, United States Forest Service (USFS) Wilderness Areas, National Wildlife Refuges (NWR), mines and quarries, Wild and Scenic Rivers, and Sites of Ritual Importance. These areas are eliminated from the analysis.

To locate the Macro Corridors in the most suitable areas, the project team identified three scenarios, as follows:

1. Rebuilding or paralleling existing transmission lines;
2. Paralleling existing road rights-of-way; and
3. Crossing undeveloped land (cross-country).

A weighting system was designed to identify areas where overhead electric transmission line development is most or least suitable for each of these scenarios. A suitability value is assigned to each GIS feature in the Macro Corridor data layers. The assigned values range from 1–9 reflecting the suitability of each grid cell. A value of 1 identifies an area of greatest suitability and 9 is an area of least suitability. A feature is suitable if a transmission corridor could cross it with little impact, for example, open land. A feature is considered unsuitable if a transmission line going through it would have some adverse consequences, such as steep terrain or a densely populated area.

Areas that have High Suitability for an Overhead Electric Transmission Line (1–3) – These are areas that do not contain known sensitive resources or physical constraints, and therefore should be considered as suitable areas for the development of Macro Corridors. Examples might include open land, pasture, or rebuilding an existing transmission line.

Moderate Suitability for an Overhead Electric Transmission Line (4–6) – These are areas that contain resources or land uses that are moderately sensitive to disturbance or that present a moderate physical constraint to overhead electric transmission line construction and operation. Resource conflicts or physical constraints in these areas generally can be reduced or avoided using standard mitigation measures. Examples might include primary road crossings.

Low Suitability for an Overhead Electric Transmission Line (7–9) – These are areas that contain resources or land uses that present a potential for significant impacts that cannot be readily mitigated. Locating a transmission line in these areas would require careful siting or special design measures. Examples might include forested wetlands or dense urban areas. Note that these areas can be crossed, but it is not desirable to do so if other alternatives are available.

Once all the data for the project area are collected, entered into the Macro Corridor GIS database, and numeric suitability values assigned to each Feature, a suitability surface is created for each scenario.

The Macro Corridor Siting Model uses a "Least Cost Path" (LCP) algorithm. This algorithm calculates the sum of the suitability values of the cells it crosses as it works its way across a suitability surface from the starting point to the end point. The LCP calculation is a function of the number of cells crossed (distance) and the suitability values in the individual cells. For example, the algorithm can cross 9 cells with a suitability value of 1 for the same "cost" as crossing 1 cell with a value of 9. As a result the path will avoid less suitable (high "cost" cells), but still follow the most direct path possible between the two end points. Note that, if all the cells have the same score, the resulting path between the two points would be a straight line. The suitability surface is transformed into an accumulation surface in which each cell is assigned the sum of the suitability values required to reach it from the starting point.

Generating Macro Corridors from the suitability surfaces

There are many possible paths that connect the end points of the study project. After the three suitability surfaces are generated, the LCP algorithm calculates the value of the alternative paths to connect the two end points. A histogram of path values is developed for each surface. Figure 1 shows the Macro Corridor

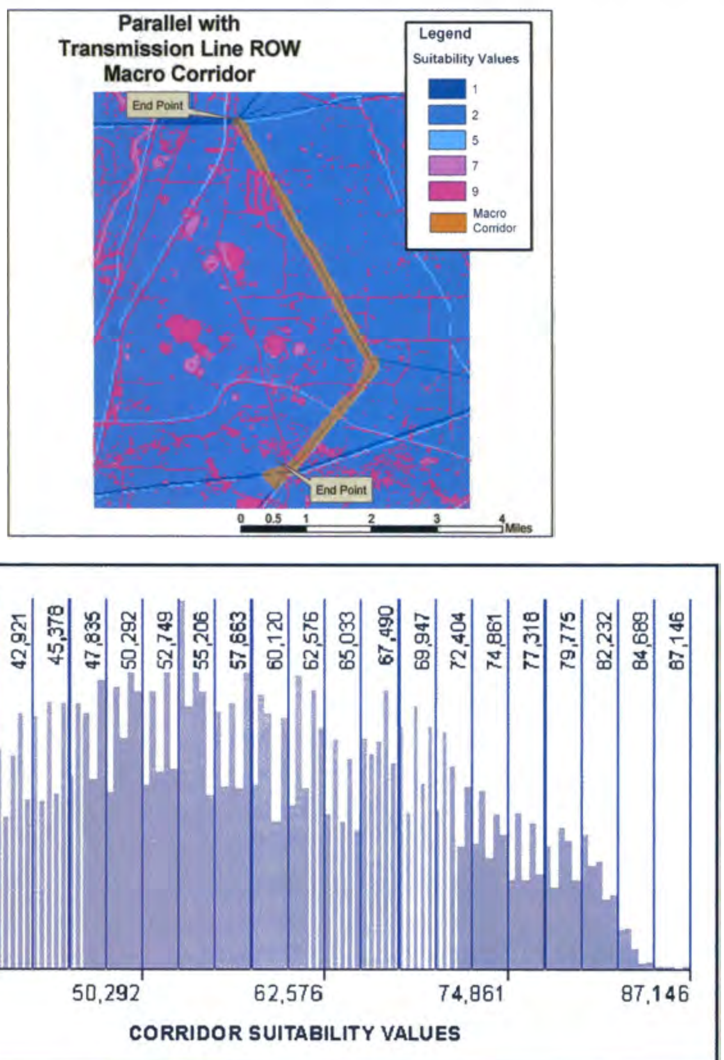

Fig. 1. Macro Corridor parallel with existing transmission line ROW.

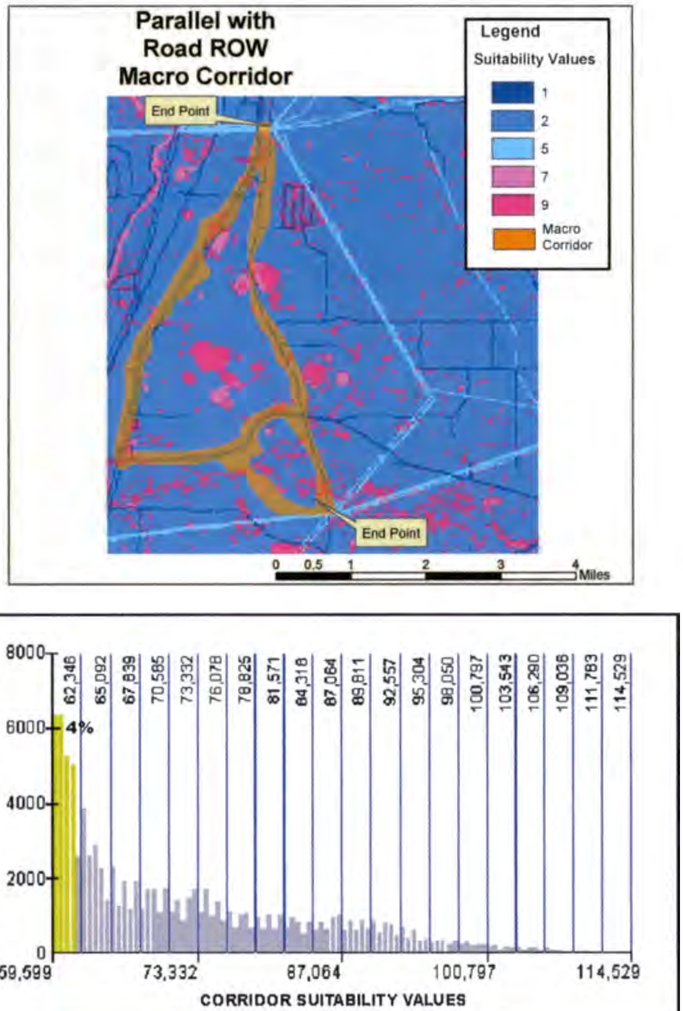

Fig. 2. Macro Corridor parallel with existing road ROW.

for the rebuilding or paralleling existing transmission line scenario and the associated histogram of cumulative suitability totals for all possible routes across the study area. The corridor shown includes the most suitable 2 percent of the possible routes between the selected start and end points. Note that a larger percentage of the possible routes would produce a wider Macro Corridor. Figure 2 shows the Macro Corridor that parallels existing road rights-of-ways; and Fig. 3 shows the Macro Corridor that crosses undeveloped lands (cross-country).

After the Macro Corridor for each scenario is identified, the three corridors are merged into one Composite Macro Corridor as shown in Fig. 4 below. The outer boundaries of this composite become the boundaries for the study are within which more detailed data will be collected.

Step 2. Alternative Corridor Generation

During Step 2, Alternative Corridors are generated within the Macro Corridor boundaries. The project team identified three Perspectives for which Alternatives Corridors should be generated, as follows:

- Protecting existing communities and cultural resources (Built Environment Perspective);
- Protecting plants, animals and water resources (Natural Environment Perspective); and
- Minimizing costs and schedule delays (Engineering Requirements Perspective).

These three Perspectives represent the major issues in transmission line siting and provide a framework for organizing related Data Layers. A fourth Perspective is created by combining these three Perspectives, as follows:

- A composite of the Built, Natural and Engineering alternatives (Simple Combined Perspective).

Following Macro Corridor Generation, more detailed data are collected to produce Alternative Corridors within the Macro Corridors. Some data layers are gathered from existing ("off-the-self") data warehouses, while others are created specifically for each project based on aerial photo interpretation. Just as in the Macro Corridor Phase of the methodology, however, some of the data for Alternative Corridor Generation must be derived. For example, United States Geological Survey Digital Elevation Maps (USGS DEMs)

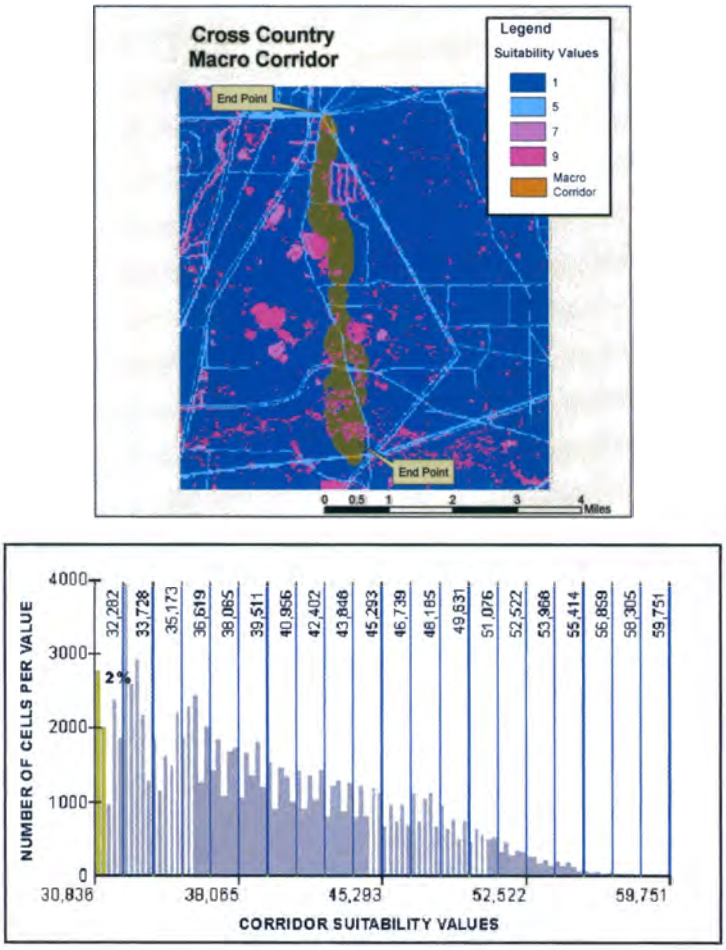

Fig. 3. Cross country Macro Corridor.

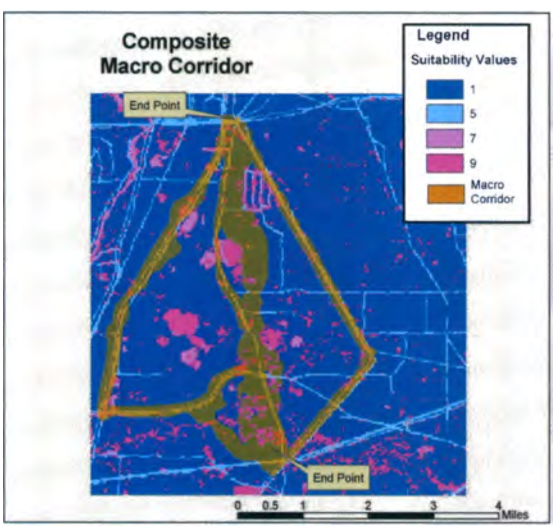

Fig. 4. Composite Macro Corridor.

are acquired as "off-the-shelf" data, but slope must be derived from the DEMs to be included in the model.

Because the 30-meter Land Use/Land Cover map used for Macro Corridor Generation is not detailed enough to define Alternative Corridors, more detailed datasets are developed from digital orthophotography. This orthophotography is also used to "derive" data for specific dataset. One example of this derived data is the building dataset. Although buildings can be seen in the orthophotography, the buildings themselves are not used in Alternative Corridor Generation. Information on the density of buildings, and proximity to buildings is derived from the building dataset using standard functionality commonly available in GIS software. Then, the derived datasets are inserted into the GIS and used for alternative corridor siting.

The first step in the Alternative Corridor Generation process is to remove all Avoidance Areas from the Alternative Corridor database. Removing these sensitive areas from consideration protects them during the Alternative Corridor site selection process.

As previously stated in the Macro Corridor Phase, Avoidance Areas are not suitable for locating overhead electric transmission lines. The GIS Siting Model will avoid these areas except in specific situations. One example of such an exception is where a road right-of-way is adjacent to a military base. The existence of the road "trumps" the military base as an Avoidance Area by weighting the roadside edge grid cells as suitable for as a transmission line corridor.

Like most GIS databases the data used in Alternative Corridor Generation are organized into a number of Data Layers that are important in siting a transmission line, i.e. slope, building density and wetlands. Each Data Layer contains a number of Features that are assigned a value ranging from 1 to 9. Features may be distinct categories. For example, the Land Cover Data Layer contains the following Features: managed pine, forests, row crops, open land and developed land. Data Layers may also contain continuous numerical ranges, as with building density or topographic slopes.

At the highest level, the Data Layers are grouped into three Perspectives: Built Environment, Natural Environment, and Engineering Requirements. Each of these Perspectives reflects a distinct viewpoint on critical siting issues.

Feature value calibration

Stakeholders were asked to calibrate the Features using the Delphi Process. This collaborative process involves iterative discussion and structured input designed to assist each stakeholder group in reaching consensus as they calibrated the Features.

The suitability of each Feature was calibrated on a common 1 to 9 scale. Putting Features into a common 1 to 9 scale allows the Data Layers to be mathematically combined without being distorted by differences in measurement scale. For example, if one foot is measured as 30.48 centimeters rather than 12 inches the larger number would give that Data Layer more weight in any mathematic operation even though the physical length represented is the same. Putting all of the data on a common scale allows the data to be combined into Perspectives. These Feature rankings were developed through stakeholder input. For example, a new overhead electric transmission line right-of-way that parallels an existing transmission line was considered more suitable than one that parallels a scenic highway. Therefore, those areas adjacent to the existing transmission line would receive a 1 while those adjacent to the scenic highway would receive a 9.

Data Layer weighting

The Data Layers were weighted to reflect their relative importance using the Analytical Hierarchy Process (AHP). This collaborative procedure involved pairwise comparison of the Data Layers to determine the relative importance of each layer. The result is an importance weight assigned to each map layer. Once weighted, the Data Layers are combined to form either the Built, Natural or Engineering Perspectives. The stakeholders and the project team collaborated to develop the Data Layer weights. These weights reflect the importance of each Data Layer in the Overhead Electric Transmission Line Siting Methodology.

Perspectives

Individual Data Layers were combined to form three distinct perspectives. These Perspectives were the Built Environment, Natural Environment, and Engineering Requirements. The Built Environment Perspective recognizes that in recent years the most significant opposition to overhead electric transmission lines came from residential neighborhoods and over special places of value to the community. The Natural Environment Perspective sought to minimize the disturbance to ecological resources and natural habitat. The Engineering Requirements Perspective focused on minimizing the cost of construction by seeking the shortest path, while avoiding areas that pose significant construction obstacles. The Simple Combination Perspective places an equal weighting on the Built Environment, Natural Environment and Engineering Requirements Perspectives to form a composite perspective. These four different perspectives produce a set of distinct Alternative Corridors that are evaluated and compared prior to developing Alternative Routes.

Built Environment Perspective

The purpose of the Built Environment Perspective is to select routes that avoid or minimize impacts to communities. The Built Environment Perspective provides protection to all buildings including commercial, industrial and residential buildings by designating them as "Avoidance Areas." Additional protection is provided to each building by adding a 300-foot buffer with a high weight around each building centroid. Listed National Landmark sites, listed and eligible NRHP districts and sites and their properties and traditional cultural sites are treated as "Avoidance Areas" providing maximum protection.

Stakeholders requested that land use be given more emphasis in this Perspective. The project team created three land use categories in the Land Use Layer: residential, non-residential developed and undeveloped. The Proposed Development Layer anticipates future development that cannot be identified on an aerial photograph by including all projects i.e. subdivisions, commercial developments, public facilities, etc. that have been filed for permits with the relevant local government.

One of the most suitable areas for an overhead electric transmission line is along a property line of an undeveloped parcel. Land lot lines, comparable to section lines in the West, and edges of fields identified on aerial imagery are included in the Land Division Layers are preferred to other locations because often they are associated with property boundaries. Spannable lakes and ponds are also included in the Built Environment Perspective because they are considered amenity features that are less preferred than other areas.

Taken together these layers capture the salient features of the Built Environment Perspective. The Built Environment corridors will avoid developed areas whenever possible. Table 1 below shows the relative importance applied to the seven map layers forming the Built Environment Perspective. Note that building

Table 1. Built Environment Perspective data layer weights

Data layer	Weights
Proximity to Buildings	11.5%
Eligible NRHP Structures	13.9%
Building Density	37.4%
Proposed Development	6.3%
Spannable Lakes and Ponds	3.8%
Land Divisions	8.0%
Land Use	19.1%

Table 2. Natural Environment Perspective data weights

Data layer	Weights
Public Lands	16.0%
Streams/Wetlands	20.9%
Floodplain	6.2%
Land Cover	20.9%
T&E Species Habitat	36.0%

density has the most influence (37.4%) and is nearly twice as important as land use considerations. As previously discussed, the AHP process involving group collaboration with stakeholders was used to determine the weights.

Natural Environment Perspective

The Natural Environment Perspective seeks to minimize the effects from overhead electric transmission lines construction and maintenance on sensitive natural resources. Federal and state environmental regulations require the identification and protection of environmentally sensitive areas. Environmental permits are required from various levels of government including federal, state and local.

Because of their span length and the small footprint for structure placement, overhead electric transmission line construction and maintenance activities generally have minor impacts on the natural environment. There are two areas of concern, however, that must be accounted for during data collection: 1) habitat fragmentation and 2) the encroachment on environmentally sensitive areas. These concerns can be avoided by minimizing the amount of the transmission line rights-of-way located in environmentally sensitive undeveloped areas.

This perspective includes five data layers: 1) public lands, 2) streams and wetlands, 3) floodplains, 4) land cover, and 5) wildlife habitat. Although some Public Lands such as state and National Parks, city and county parks, Wild and Scenic Rivers, United States Forest Service (USFS) Wilderness Areas, and Wildlife Refuges were included as Avoidance Areas, the remainder have been included as part of the Natural Environment Perspective. Inclusion in this perspective ensures that impacts to these areas would be considered in the routing process.

Many agencies have developed data layers that can be used in the planning of overhead electric transmission line routes. The commonly available datasets include: United States Fish and Wildlife's (USFW) National Wetland Inventory (NWI), Federal Emergency Management Agency's (FEMA) floodplain maps and U S Geological Survey's (USGS) National Hydrological Dataset. State Heritage programs often provide some level of information on the distribution of threatened and endangered species within a state.

To minimize impacts to streams and wetlands during overhead electric transmission line construction and maintenance, it is critical to collect accurate data about their location and characteristics during the routing step. Streams with flows greater than 5 cubic feet/second (cfs) create construction and maintenance access problems. In Georgia, trout streams are protected with a 100-foot vegetative buffer (50 feet either side of the stream).

FEMA Q3 Flood information is used for the Floodplain delineation, because National Environmental Policy Act (NEPA) regulations prohibit steel tower structures being located in a floodplain because they can trap debris and obstruct the flow.

Land Cover data are digitized from orthophotography and includes the following land cover types: managed pine, row crops and horticulture, hardwood mixed and natural forests, open land, and developed lands. Other categories in the Land Cover Data Layer include land use information, such as transportation; utility rights-of-way; low intensity urban; high intensity urban; clear cut/sparse vegetation; quarries/strip mines; rock outcrops; deciduous forest; mixed forest; coniferous forest; golf courses; pasture; row crop; forested wetland; coastal marsh; and non-forested wetland.

In Georgia, the difficulty in acquiring timely and accurate data on threatened and endangered species is a significant problem. For this project, the Threatened and Endangered Species Habitat Data Layer is used to represent the location of terrestrial endangered species and the Natural Area Data Layer is used as a surrogate for listed plant species. Both of these Data Layers come from the Georgia GAP analysis program. These Data Layers include potential distribution of terrestrial vertebrate and a map of natural vegetation.

Engineering Requirements Perspective

The criteria in this Perspective focused on the engineering requirements for routing, constructing, and maintaining overhead electric transmission lines. Engineering stakeholders included engineers and scientists from utilities and state agencies involved in site selection for linear facilities. The group provided specific knowledge regarding the co-location of power lines with other linear features, including pipelines, roadways and other power lines. Within this Perspective there are three Data Layers: Linear Infrastructure, Slope, and Intensive Agriculture.

Table 3. Engineering Requirements Perspective data weights

Data layer	Weights
Linear Infrastructure	48.3%
Slope	9.10%
Intensive Agriculture	42.6%

If the Data Layers were equally suitable, the engineering solution would be a straight line connecting two endpoints. Since this rarely occurs, the Engineering Requirements Perspective utilizes the Data Layer suitability information to represent actual conditions. Categories in the Linear Infrastructure Data Layer include rebuilding or paralleling existing transmission lines or paralleling (co-locating) with other linear infrastructure.

The most cost effective solution with the least impact to resources in the Natural Environment Perspective and Built Environment Perspective is rebuilding an existing transmission line in its existing right-of-way. Stakeholders ranked the rebuild alternative as the most suitable alternative followed by paralleling (co-locating with) existing linear facilities. Paralleling existing linear facilities is driven primarily by construction, maintenance access and cost considerations.

Another engineering consideration is Slope. Slopes less than 15 percent are most suitable for the construction and maintenance of an overhead electric transmission line. Slopes of 16–30 percent pose a moderate constraint by increasing construction costs and having a greater chance of erosion. Slopes greater than 30 percent should be avoided, if possible, because of the high costs of construction and maintenance. Construction costs in these areas are significantly greater due to soil stabilization requirements, equipment constraints, environmental permits, and mitigation requirements. Some extreme cases may require construction and maintenance work to be performed from the air.

Three types of agriculture that pose significant engineering constraints are included in the Intensive Agriculture Data Layer: center pivot irrigation, pecan orchards, and fruit orchards. Avoiding these areas provides an opportunity to minimize the cost of affecting expensive orchards and agricultural irrigation facilities.

As in the Macro Corridor Phase, a histogram of composite cell values is generated and interpreted. In the case of Alternative Corridor Generation, it is run on surfaces for each of the Built Environment, Natural Environment and Engineering Requirements Perspectives. The histogram is used to choose the corridors for each of the three perspectives. The boundaries of these corridors are chosen by the first statistical break in the histogram. Typically, the statistical break occurs between 1 and 5 percent. The Alternative Corridors are shown on the maps below: Built Environment Alternative Corridor, Engineering Requirements Alternative Corridor, Natural Environment Alternative Corridor, and Simple Average Alternative Corridor (see Figs. 5–8).

Alternative Corridors are generated by emphasizing the different Perspectives. Emphasis is achieved by combining the three preference surfaces with a weighted average in which one of the Perspectives

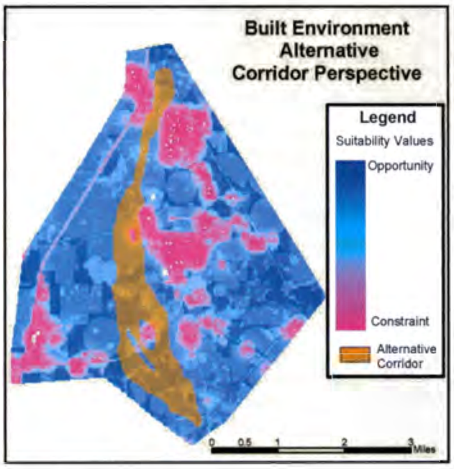

Fig. 5. Built Environment Corridor.

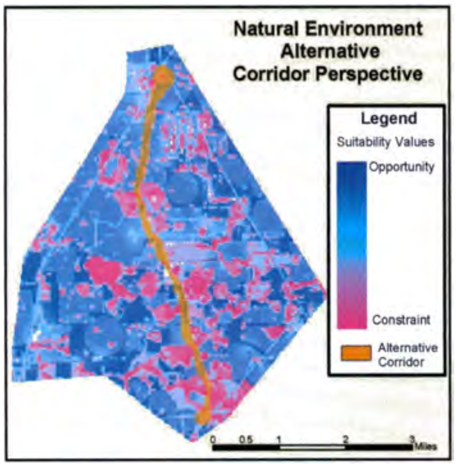

Fig. 6. Natural Environment Corridor.

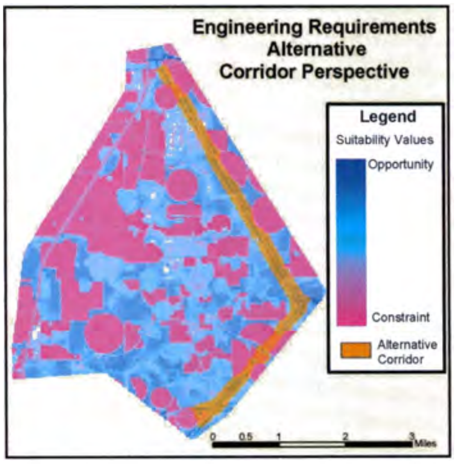

Fig. 7. Engineering Requirements Corridor.

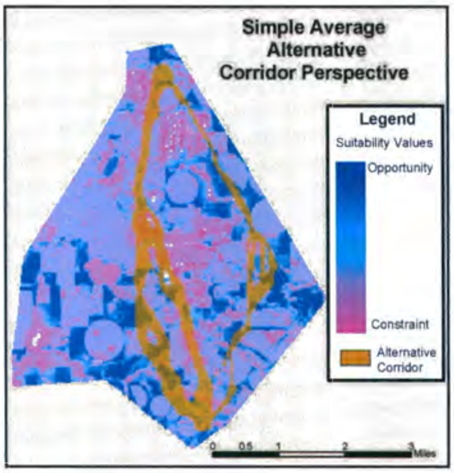

Fig. 8. Simple Average Corridor.

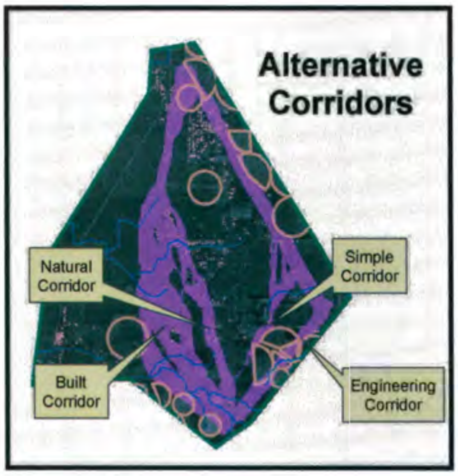

Fig. 9. Environmental, Natural, Engineering and Simple Combination Corridors Combined.

is considered five times more important than the other two. The testing of weight averaging on various projects demonstrated that the weighting of five times was most effective in emphasizing one Perspective over the others while still retaining some influence from the other two Perspectives.

The Built Environment Alternative Corridor Perspective is generated by weighing the Built Perspective Data Layers five times more than the Natural and Engineering Perspectives. In a similar manner, Engineering and Natural Alternative Corridor Perspectives are over-weighted to identify distinct solutions that respond to each Perspective, as demonstrated in Figs. 5–8.

In addition to the corridors generated for each Perspective, a simple average preference surface is used to establish a consistent base line for all three Perspectives. The Alternative Corridors are combined to identify the optimal "decision space" for locating an overhead electric transmission line considering the different siting perspectives. A proposed route venturing outside the combined Alternative Corridors is suboptimal from all three Perspectives and would need to be justified by extenuating factors not included in the model's set of map criteria.

Step 3. Alternative Route delineation

The LCP algorithm generates Alternative Corridors for each of the three perspectives emphasizing: Built, Natural, Engineering factors and an overall Simple Average Combination of all three. This algorithm generates an "Optimal Path" in each corridor. As with the other two phases, additional detailed data are collected for areas within the Alternative Corridors including property lines and types of buildings. By waiting until these Alternative Corridors have been identified before collecting this very detailed data, the total time and cost to the project are greatly reduced.

Staff from the areas of engineering, land acquisition and environmental form the siting team. This team has access to the optimal path created by the automated system and can query the entire GIS database. This team manually sketches in Alternative Route centerlines using all of the available data. The team can produce individual route segments that can be combined in different ways to form alternative routes. GTC is experimenting with more completely automated techniques for route creation, but to date none has proven to be superior to the expert judgment of an experienced siting team.

Step 4. Evaluation and selection of the Preferred Route

This final step in the siting process evaluate the advantages and disadvantages of the Alternative Routes and selects a of Preferred Route. This evaluation is based on an extensive set of siting criteria as well as summaries of Data Layers, spreadsheet processing, interactive geo-queries, and other quantitative and qualitative metrics. Variations between the Built Environment Perspective, Natural Environment Perspective, and Engineering Requirements Perspective can be illustrated to the project siting team by using this Map Overlap Analysis.

In analyzing a composite Alternative Route, the GIS Siting Model isolates the evaluation criteria for all Data Layers. The results can be reported in a variety of formats: as a map display, a graphic or summary statistics.

Table 4, Tabular Summary of Alternative Routes, shows an example spreadsheet of summary information (rows) for several Alternative Routes (columns). Corridor Analyst™ software is used to summarize the evaluation metrics in terms of counts for the siting team discussion of relative lengths and acres of easement.

Metrics, such as the number of relocated residences or length of the route passing through natural forests, are used to guide discussions comparing the advantages and disadvantages of the Alternative Routes. These discussions help organize and focus the siting team's review, as well as provide ample opportunity for free exchange of expert experience and opinion.

Table 4. Tabular summary of alternative routes

DATA FOR ALL ROUTES

Built	**Route A**	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**
Feature	Unit	Unit	Unit	Unit	Unit	Unit
Relocated Residences (within 75′ Corridor)	0.0	0.0	1.0	0.0	1.0	0.0
Normalized	0.0	0.0	1.0	0.0	1.0	0.0
Proximity to Residences (300′)	5.0	37.0	13.0	9.0	141.0	10.0
Normalized	0.0	1.0	0.3	0.1	0.3	0.2
Proposed Developments	2.0	0.0	1.0	0.0	0.0	0.0
Normalized	1.0	0.0	0.5	0.0	0.0	0.0
Proximity to Commercial Buildings (300′)	3.0	4.0	1.0	1.0	1.0	5.0
Normalized	0.5	0.8	0.0	0.0	0.0	1.0
Proximity to Industrial Buildings (300′)	1.0	0.0	0.0	0.0	3.0	3.0
Normalized	0.3	0.0	0.0	0.0	1.0	1.0
School, DayCare, Church, Cemetery, Park Parcels (#)	8.0	2.0	2.0	1.0	1.0	1.0
Normalized	1.0	0.1	0.1	0.0	0.0	0.0
NRHP Listed/Eligible Strucs./Districts (1500′ from edge of R/W)	2.0	1.0	0.0	0.0	0.0	0.0
Normalized	1.0	0.5	0.0	0.0	0.0	0.0
Natural						
Natural Forests (Acres)	1.2	3.4	5.8	7.0	9.6	10.7
Normalized	0.0	0.5	0.5	0.6	0.9	1.0
Stream/River Crossings	4.0	5.0	4.0	4.0	6.0	6.0
Normalized	0.0	0.5	0.0	0.0	1.0	1.0
Wetland Areas (Acres)	2.0	1.9	5.4	5.9	6.9	7.5
Normalized	0.0	0.0	0.6	0.7	0.9	1.0
Floodplain Areas (Acres)	4.3	2.6	8.3	7.4	6.4	4.3
Normalized	0.3	0.0	1.0	0.9	0.7	0.3
Engineering						
Length (Miles)	12.5	11.2	15.3	17.2	11.4	16.3
Normalized	0.2	0.0	0.4	1.0	0.0	0.5
Miles of Rebuild with Existing T/L*	5.2	4.7	5.1	4.6	4.8	4.8
Normalized	1.0	0.2	0.5	0.0	0.4	0.3
Inverted	0.0	0.8	0.2	1.0	0.6	0.7
Miles of Co-location with Existing T/L*	2.58	1.25	8.5	2.36	3.69	9.5
Normalized	0.2	0.0	0.9	0.1	0.3	1.0
Inverted	0.8	1.0	0.1	0.9	0.7	0.0
Miles of Co-location with Roads*	0.0	0.1	0.0	0.1	0.8	0.8
Normalized	0.0	0.2	0.0	0.2	1.0	1.0
Inverted	1.0	0.8	1.0	0.8	0.0	0.0
Number of Parcels	4.05	1.04	3.63	0.62	0.43	0.23
Normalized	1.0	0.2	0.9	0.1	0.1	0.0
Total Project Costs	45	34	48	37	34	34
Normalized	0.8	0.0	1.0	0.2	0.0	0.0

Evaluation Metrics
Relocated Residences
Proximity of Residences
Proposed Developments
Proximity to Commercial Buildings
Proximity to Industrial Buildings
School, Daycare, Church, Cemetery, Park Parcels
NRHP Listed/Eligible Structures/Districts
Natural Forests
Stream/River Crossings
Wetland Areas
Floodplain Areas
Total Length
Miles of Rebuild
Miles of Co-location
Number of Parcels
Total Project Costs

Table 5. Evaluating alternative routes

Built	33%	Route A	Route B	Route C	Route D	Route E	Route F
Feature		Unit	Unit	Unit	Unit	Unit	Unit
Relocated Residences (within 75′ Corridor)	44.3%	0.00	0.00	1.00	0.00	1.00	0.00
Weighted		0.00	0.00	0.44	0.00	0.44	0.00
Proximity to Residences (300′)	13.1%	0.00	1.00	0.25	0.13	0.28	0.16
Weighted		0.00	0.13	0.03	0.02	0.04	0.02
Proposed Residential Developments	5.4%	1.00	0.00	0.50	0.00	0.00	0.00
Weighted		0.05	0.00	0.03	0.00	0.00	0.00
Proximity to Commercial Buildings (300′)	3.6%	0.50	0.75	0.00	0.00	0.00	1.00
Weighted		0.02	0.03	0.00	0.00	0.00	0.04
Proximity to Industrial Buildings (300′)	1.8%	0.33	0.00	0.00	0.00	1.00	1.00
Weighted		0.01	0.00	0.00	0.00	0.02	0.02
School, DayCare, Church, Cemetery, Park Parcels (#)	16.3%	1.00	0.14	0.14	0.00	0.00	0.00
Weighted		0.16	0.02	0.02	0.00	0.00	0.00
NRHP Listed/Eligible Strucs./Districts (1500′ from edge of R/W)	15.5%	1.00	0.50	0.00	0.00	0.00	0.00
Weighted		0.16	0.08	0.00	0.00	0.00	0.00
TOTAL	100.0%	0.40	0.26	0.53	0.02	0.50	0.07
WEIGHTED TOTAL		**0.13**	**0.09**	**0.17**	**0.01**	**0.16**	**0.02**
Natural	33%						
Natural Forests (Acres)	9.3%	0.00	0.54	0.49	0.61	0.88	1.00
Weighted		0.00	0.05	0.05	0.06	0.08	0.09
Stream/River Crossings	38.0%	0.00	0.50	0.00	0.00	1.00	1.00
Weighted		0.00	0.19	0.00	0.00	0.38	0.38
Wetland Areas (Acres)	40.3%	0.02	0.00	0.62	0.72	.090	1.00
Weighted		0.01	0.00	0.25	0.29	0.36	0.40
Floodplain Areas (Acres)	12.4%	0.29	0.00	1.00	0.85	0.67	0.29
Weighted		0.04	0.00	0.12	0.11	0.08	0.04
TOTAL	100.0%	0.04	0.24	0.42	0.45	0.91	0.91
WEIGHTED TOTAL		**0.01**	**0.08**	**0.14**	**0.15**	**0.30**	**0.30**
Engineering	33%						
Miles of Rebuild with Existing T/L*	65.6%	1.00	0.16	0.84	0.00	0.43	0.32
Weighted		0.66	0.11	0.55	0.00	0.28	0.21
Miles of Co-location with Existing T/L*	19.2%	2.58	1.25	8.50	2.36	3.69	9.50
Weighted		0.50	0.24	1.63	0.45	0.71	1.82
Miles of Co-location with Roads*	7.8%	0.84	1.00	0.12	0.87	0.70	0.00
Weighted		0.07	0.07	0.01	0.07	0.05	0.00
Total Project Costs	7.4%	4.05	1.04	3.63	0.62	0.43	0.23
Weighted		0.30	0.08	0.27	0.05	0.03	0.02
TOTAL	100.0%	1.52	0.50	2.46	0.57	1.08	2.05
WEIGHTED TOTAL		**0.50**	**0.17**	**0.81**	**0.19**	**0.36**	**0.68**
SUM OF WEIGHTED TOTALS		**0.65**	**0.33**	**1.12**	**0.34**	**0.82**	**1.00**

FOR TOP 3–5 ROUTES (INTERNAL)

EXPERT JUDGMENT	Sample weights			
	Per Project	**Route A**	**Route B**	**Route D**
Visual Issues	5%	1	5	1
Weighted		0.05	0.25	0.05
Community Issues	25%	1	5	3
Weighted		0.25	1.25	0.75
Schedule Delay Risk	30%	2	5	1
Weighted		0.60	1.50	0.30
Special Permit Issues	30%	4	5	1
Weighted		1.20	1.50	0.30
Construction/Maintenance Accessibility	10%	5	1	2
Weighted		0.50	0.10	0.20
TOTAL	**100%**	**2.6**	**4.6**	**1.6**

Expert Judgment

Visual Concerns (5%)
Community Concerns (25%)
Schedule Delay Risk (30%)
Special Permit Issues (30%)
Construction/Maintenance Accessibility (10%)

. . .the evaluation metrics are normalized and assigned weights to derive a relative score for the alternative routes. The siting team applies expert judgment to rank the top three routes (routes A, B, and D).

The Siting Team uses evaluation metrics that are normalized and assigns weights developed using AHP to derive a relative score for each Alternative Route. The scores are combined for the three Perspectives (Built Environment Perspective, Natural Environment Perspective and Engineering Requirements Perspective), and then totaled for an overall score. The numerical score provides an objective reference for comparing Alternative Routes and stimulates discussion of their relative merits.

The left column of Table 5, Evaluating Alternative Routes, shows the translation of the "raw" evaluation metrics to a normalized and weighted score. In this example, the sub-criteria for each Perspective are assigned relative weights. For example, the Built Environment Perspective consideration of Relocated Residences is more important (40 percent) than the consideration of Proximity to Industrial Buildings (2 percent). The three perspectives are equally weighted (33 percent) in this example, but could reflect preferential treatment if a routing situation was thought to be more sensitive to one particular perspective.

The final step in the evaluation process applies expert judgment to rank the top Alternative Routes. Each member of the Siting Team ranks the top scoring routes based on their expert experience and opinion of several important considerations: visual concerns, community concerns, schedule delay risk, special permit issues, construction and maintenance accessibility, and environmental justice. The considerations are assigned relative importance weights and the individual responses are combined for an overall team ranking.

It is important to note that the specific evaluation criteria can be expanded or contracted as the unique aspects of routing situations vary. The general process of deriving and evaluating explicit metrics, however, remains the same. The format of the process is designed to encourage thorough discussion of clearly defined evaluation criteria that explicitly captures the thought process of the siting team in evaluating and selecting a final route. The process is objective, consistent, and comprehensive while directly engaging, focusing and capturing siting team deliberations.

CONCLUSIONS

As envisioned by EPRI and GTC, a successful Overhead Electric Transmission Line Siting Methodology encompasses several critical tasks: incorporating stakeholder participation into the siting process; balancing community needs and impacts to the natural environment; and integrating GIS technology with existing overhead electric transmission line siting methodology.

The project team and stakeholders accomplished the following objectives of the project:

1. Review and revision of GTC's existing Overhead Electric Transmission Line Siting Methodology;
2. Incorporation of stakeholder input into the siting methodology utilizing the AHP and the Delphi Process;
3. Development of a GIS Siting Model;
4. Increasing objectivity and predictability of results when applying the criteria to corridor and route selection; and
5. Assurance that the Overhead Electric Transmission Line Siting Methodology complied with the National Environmental Protection Act (NEPA) and other regulations.

Siting experts from the electric industry, federal and state agencies and external stakeholders participated in the Overhead Electric Transmission Line Siting Methodology development and provided feedback on its strengths and weaknesses. As confirmed by stakeholder comments, the calibration of the Features using the Delphi Process and weighting of the Data Layers using the Analytical Hierarchical Process provided a scientifically rigorous methodology.

Another achievement of the project was stakeholder input during five multi-day workshops. Transmission line siting professionals indicated that the involvement of external stakeholder throughout the development of the siting methodology was a unique approach. This approach is a significant departure from most other transmission line siting methodologies because it integrated stakeholder input into the development of the methodology and standardized the calibrating and weighting that will be applied to all subsequent projects.

GTC integrated a proprietary transmission line siting software program, Corridor Analyst™, with off-the-shelf digital data to automate the siting methodology. This GIS approach ensures a comprehensive, objective and consistent methodology for siting transmission lines that can be implemented by other electric industry companies nationwide. GTC is actively working with other members of the Georgia ITS to use this methodology when siting new overhead electric transmission lines in Georgia.

An important benefit of standardizing the Overhead Electric Transmission Line Siting Methodology is the cost savings that results from using the GIS Siting Model and off-the-shelf digital data to reduce the study area boundaries of the Macro Corridors, Alternative Corridors and Alternative Routes. Reducing the study area boundaries eliminates the need for extensive data collection and verification that is both costly and time consuming. This methodology shortens the time required for the siting portion of the transmission line construction project.

Unlike many other utilities, GTC prepares environmental documents to comply with NEPA. Among other reasons, GTC does so to be eligible for the Rural Utility Service (RUS) of the United States Department of Agriculture (USDA) to take federal action related to its project. The RUS action may, for example, involve providing a loan commitment and/or approvals necessary for GTC to construct the project. GTC's NEPA reviews and its actions must be incompliance with 7 CFR Part 1794 (RUS Environmental Policies and Procedures) and 40 CFR Part 1500 (the President's Council on Environmental Quality (CEQ) regulations for implementing NEPA), 42 USCA §§4321–4347.

The National Environmental Policy Act is the basic national charter for protection of the environment. NEPA is intended to ensure that environmental information is available to federal agencies and the public before decisions are made and before actions requiring federal involvement are taken. It helps assure that federal agencies make decisions that are based on understanding of environmental consequences. NEPA establishes policy, sets goals (Section 101), and provides means (Section 102) for carrying out the policy. Section 102(2) contains certain "action-forcing" provisions to ensure that federal agencies act according to the letter and spirit of the Act.

In part, the EPRI-GTC Model will help GTC complete its Environmental Reports. Among the benefits of the land suitability analysis underlying this approach is the improved consistency and objectivity of information that describes, explains, analyzes and discloses the direct, indirect, and cumulative environmental impacts that would result from proposed actions and alternatives. Along with its development of an advanced land suitability analytic modeling capability, GTC has adopted a standardized template for its environmental documents that are organized to include the following:

1. Information on the history of the project proposal, the purpose of and need for the project, and GTC's proposal for achieving that purpose and need;
2. A detailed description of GTC's proposed action as well as alternative methods for achieving the stated purpose: alternatives developed based on significant issues raised by the public and other agencies; a discussion of possible mitigation measures; and, a summary of the environmental consequences associated with each alternative;
3. A description of the environmental effects of implementing the proposed action and other alternatives; and
4. Additional documentation, including more detailed analyses of project-area resources.

As envisioned by EPRI and GTC, the successful Overhead Electric Transmission Line Siting Methodology should encompass several critical tasks, including compliance with the NEPA and other environmental regulations. To the extent that this process develops new transmission line siting tools, techniques and procedures that are objective, quantitative, predictable, consistent, and defensible, GTC has compiled an effective new mechanism to describe the relevant data and articulate a satisfactory explanation for selection of a preferred alternative and established a rational connection between the facts found and the choice made.

While new techniques will not end the controversies surrounding the construction of new overhead transmission lines, there are significant benefits to both utilities and the public can be realized as a result of such innovations. To the extent entities develop techniques and procedures that are objective, quantitative, predictable, and consistent to prepare, explain and document their decisions, sound public policy goals have been substantially advanced.

ACKNOWLEDGEMENTS

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Getting the Crop to Market: Siting and Permitting Transmission Lines on Buffalo Ridge, Minnesota

Michelle F. Bissonnette, Angela G.L. Piner, and Pamela J. Rasmussen

The rapid development of wind technology in southwest Minnesota has prompted the need to improve the transmission system in this area. The Minnesota Public Utilities Commission approved four major transmission line projects in 2003 to meet this need, including an 87-mile 345 kV transmission line. Northern States Power Company, d/b/a Xcel Energy, currently is involved in the State siting process with the projects and has been gathering public and agency input. Gathering the information early in the process has proven to be invaluable in deciding route locations and permitting strategies. In addition, public reception for the projects has been primarily positive since these facilities will allow additional wind generation to be developed in the area. This paper will describe the Xcel Energy projects, public reactions to the project, and the routing and siting issues, including some unique to these projects. Xcel Energy will highlight the primary lessons learned that can be used in future projects for routing transmission lines.

Keywords: Transmission line, wind, siting, routing, Xcel Energy, public involvement, Buffalo Ridge

INTRODUCTION

Project background

During the past 10 years, more than 550 megawatts (MW) of wind generation have been developed on a landform known as Buffalo Ridge, partly located in southwest Minnesota. Current projections for the region call for an additional 400 MW of wind power by 2012. This rapid growth can be contributed to the following factors:

- The Prairie Island Mandate, which required Northern States Power Company (NSP), d/b/a Xcel Energy, to have 425 MW of wind power under contract by the end of 2002. In turn, the mandate allows Xcel Energy to store on-site dry casks of nuclear waste and extends the life of the Prairie Island nuclear plant;
- The merger agreement between NSP and New Century Energy required Xcel Energy to study transmission for 825 MW of new wind power and resulted in the expansion of the transmission grid in the area; and
- Minnesota Statutes Section 216B.1691 requiring Minnesota utilities to make a good faith effort to have renewable energy sources make up 10 percent of their energy portfolios by 2015. Any new wind development, however, is presently limited by transmission outlet constraints.

The transmission system in this area currently has a generator outlet capability of approximately 260 MW and is fully subscribed due to the growth of wind generation in recent years. More transmission capacity is needed to allow for increased wind generation in the region. After studying the transmission infrastructure needs, receiving numerous interconnection requests in the area, and getting the support of several parties interested in increasing the amount of wind generation in the area, Xcel Energy filed a Certificate of Need (CON) on December 28, 2001 with the Minnesota Public Utilities Commission (PUC). The application described the need for the project and highlighted the reasons for the PUC to select the appropriate system configuration to meet the need. Xcel Energy received approval from the PUC on March 11, 2003, and currently is working on route permit applications with

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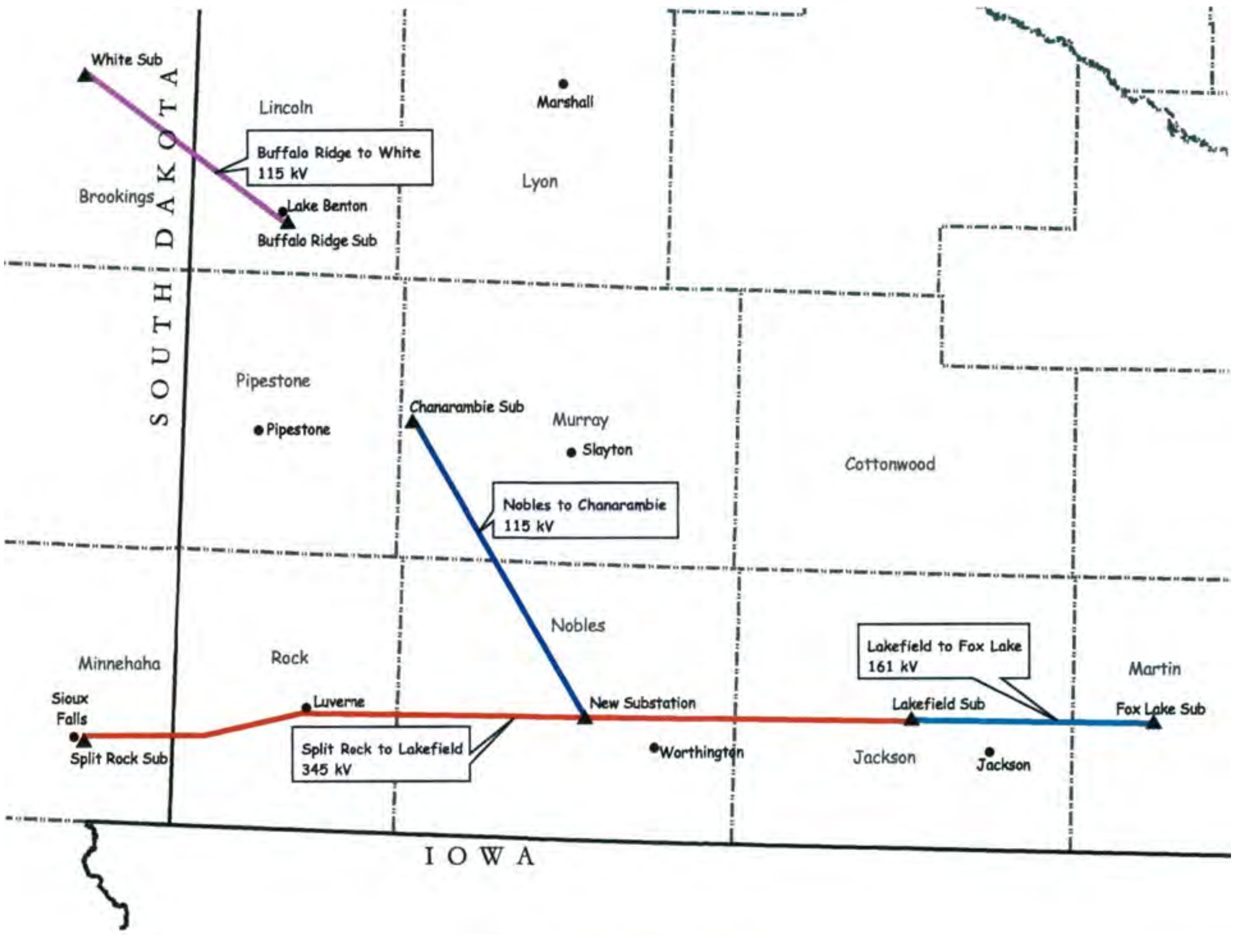

Fig. 1. Project location map.

the Minnesota Environmental Quality Board (MEQB) to site the major facilities included in the plan. The transmission line projects currently underway by Xcel Energy will increase transmission outlet capacity in and around Buffalo Ridge from the current level of 260 MW (which is fully subscribed) to approximately 825 MW by 2007. The major facilities include the following:

1. A 26-mile 161 kV transmission line from Lakefield Junction Substation near Lakefield, Minnesota, to Fox Lake Substation near Sherburn, Minnesota;
2. A 37-mile 115 kV transmission line between a new Nobles County Substation and Chanarambie Substation near Lake Wilson on Buffalo Ridge;
3. An 87-mile 345 kV transmission line between Split Rock Substation near Sioux Falls, South Dakota, and Lakefield Junction Substation, near Lakefield, Minnesota. The new Nobles County Substation will be located in the middle of the new line; and
4. A 28-mile 115 kV transmission line between Buffalo Ridge Substation southeast of Lake Benton, Minnesota, to White Substation, south of Brookings in South Dakota. The new Yankee Substation will be located midway along the new 115 kV line.

A map identifying these projects is included below.

In addition to these projects, Xcel Energy is also building a new 56-mile 115 kV transmission line project (which did not need state approvals), rebuilding 14 transmission lines (268 miles of 115 kV and 69 kV lines), and reconductoring two 115 kV transmission lines (24 miles). Substation work includes seven new substations and upgrades to 16 substations. These projects are depicted on Fig. 2, which shows the current status and expected in-service date of all the projects. The initial estimate for these projects is $160 million.

Significance of wind to the Southwest Minnesota economy

The combination of expanded use of renewable energy and the associated influx of potential economic gain in rural, primarily agricultural, regions has led to unprecedented support of the transmission line projects. Environmental groups view the increased use of a renewable energy source as a positive step and recognize the need for additional transmission capacity to support siting of renewable generation facilities.

Local farmers see it as an alternative income source. They are paid annual payments by wind developers to lease their land for turbines. Recently farmers have developed farming cooperatives to finance wind turbine projects of their own. This economic factor is a significant component in the viability of expanded wind

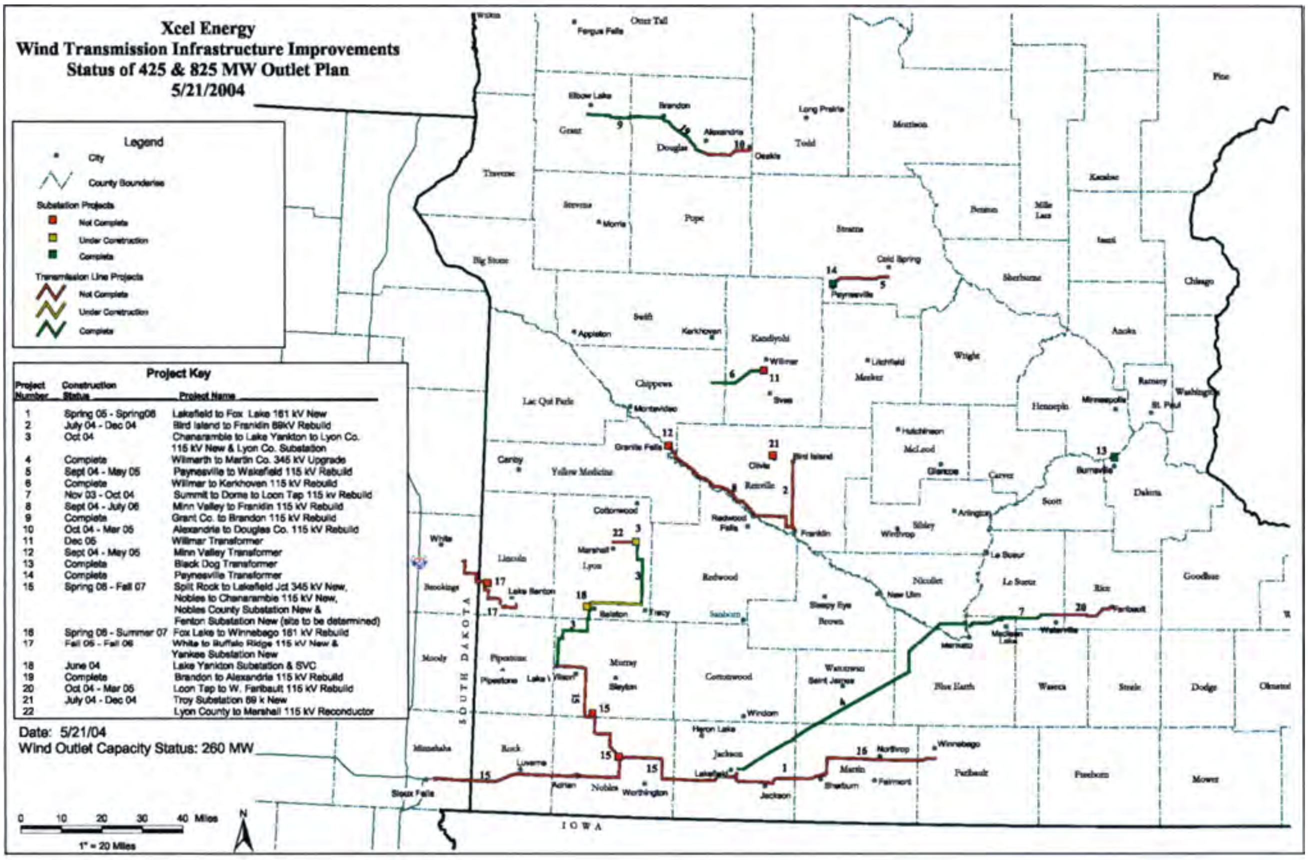

Fig. 2. Xcel Energy wind-related projects.

energy production and transmission in southwestern Minnesota. It is also a recognized factor in the State's overall renewable goals.

The Xcel Energy transmission projects are located in Lincoln, Jackson, Martin, Murray, Nobles, Pipestone, and Rock counties. The demographics of this area are an older population. The average age of the principal operator is 52. According to the 2002 Census of agriculture, farming is not the principal occupation for many of these operators. Approximately 25 percent of the principal operators have another job to supplement their income.

Wind power has become another business opportunity for many of the farmers in the area. An estimate by Wind Powering America has placed the annual payments for landowners that lease their land at two percent to four percent of the gross annual turbine revenue, about $2,000 to $4,000 per turbine. This revenue is in addition to the amount of money they make while farming the land around the turbines. The wind turbines in southwest Minnesota typically cause a loss of 0.7 acres of land per turbine and access road. The remaining land can be farmed. The Union of Concerned Scientists estimates that typical farmers and ranchers with good wind resources could increase the economic yield of their land by 30–100 percent.

The development of wind energy has been important in diversifying and strengthening the economic base of southwestern Minnesota. In a recent case study of one of the first wind projects in the area, Lake Benton I, during the construction phase of the project, eight jobs and $98,000 in personal income was supported by the town of Lake Benton, primarily in the trade and services industries. During the operation and maintenance phase of Lake Benton I, a total of 31 jobs, primarily in the transportation, communication, and public utilities industries, supported $909,000 in annual personal income in Lincoln County. In addition to the creation of jobs and personal income, the development generated $611,200 in county property taxes in 2000, representing 13 percent of the property taxes collected in Lincoln County.

A joint report by the Minnesota Project, Windustry, and the Southwest Regional Development Commission estimates that each 100 MW of new wind development in southwest Minnesota could be expected to generate about $250,000 per year in direct lease payments to landowners. Property taxes on wind facilities are changing as a result of tax changes enacted in 2002 by the State legislature. For example, a 100 MW wind facility will generate approximately $370,000 in tax revenue for the entire life of the project.

Wind development has become an important fixture for economic development in the rural communities of southwestern Minnesota. This has resulted in what Xcel Energy has seen as "unusual" reactions to their

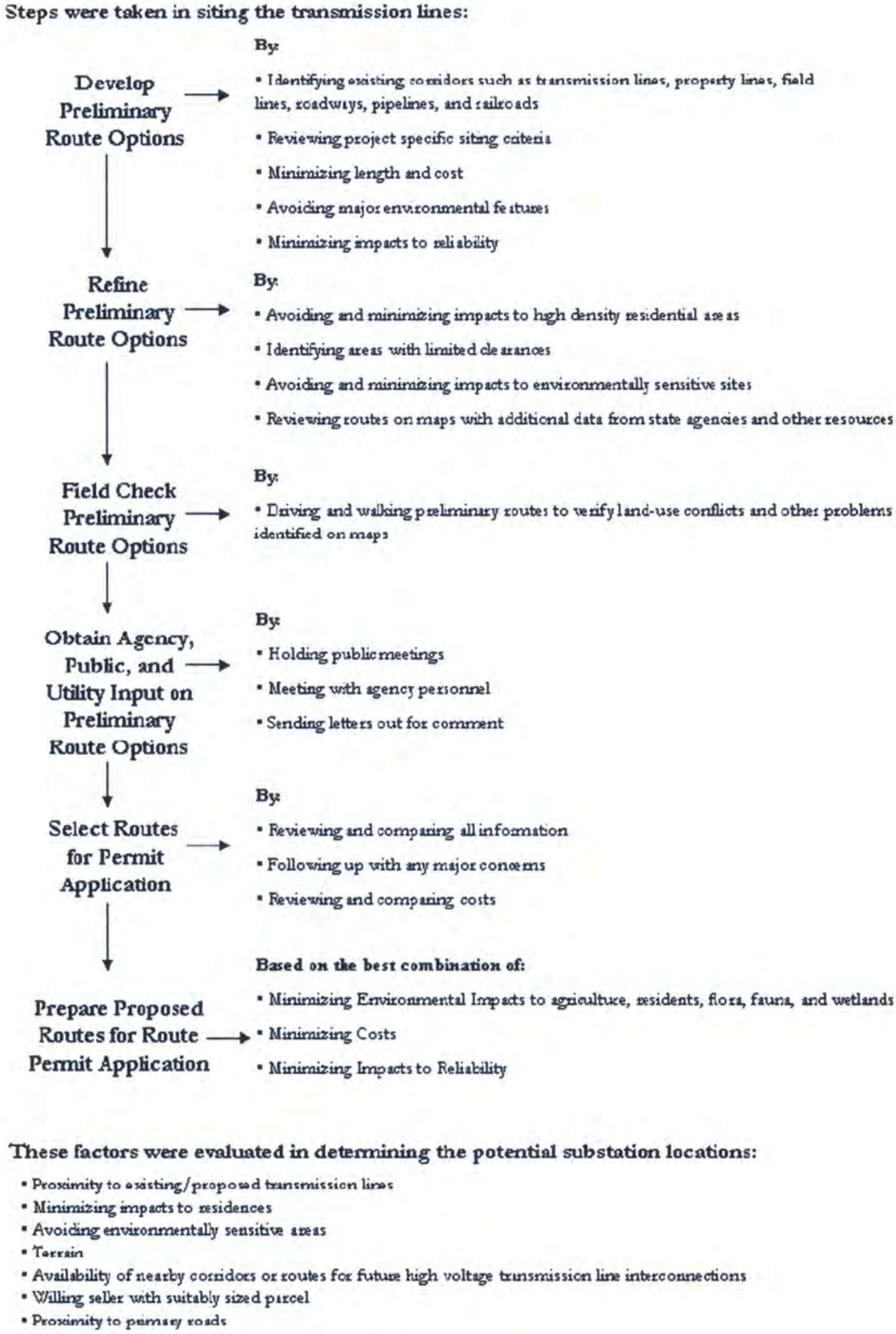

Fig. 3. Facility siting.

proposals to build four rather large transmission lines in the rural landscape.

Facility siting

Siting of the major projects began during the CON process and then proceeded in earnest once the CONs were granted. In general, Xcel Energy's process for siting these transmission lines and substations is shown on Fig. 3.

Much of this process is GIS-dependent. Several data sets available in Minnesota were utilized to identify potential routes and effectively evaluate the routes. These results are verified in the field and additional information is supplied.

UTILITY PERMIT REQUIREMENTS IN MINNESOTA

Certificate of Need process – Minnesota Public Utilities Commission

A utility must acquire two major approvals for high voltage transmission lines in Minnesota. The first is a CON from the Minnesota PUC, which is required for any transmission line greater than 200 kV *or* any transmission line greater than 100 kV and more than 10 miles long (or crosses the state line) (Minn. Stat. §116D.04). The PUC process can take six to 12 months once the application is submitted. To be granted a CON, the utility must demonstrate the proposed line will support the future adequacy, reliability, and efficiency of the energy supply, as well as show that there is no reasonable and prudent alternative and that the design will be compatible with protection of the natural and socioeconomic environments.

Route Permit process – Minnesota Environmental Quality Board

The second permit is a Route Permit from the Minnesota Environmental Quality Board (EQB), which is awarded following the requirements of the Power Plant Siting Act (Minn. Stat. §§116C.51 to 116C.69). The utility prepares a route permit application that identifies impacts to the human and natural environment. The route permit can follow one of two review processes, as follows:

1. Full Process: In this process the utility must identify a preferred route and an alternative route in its

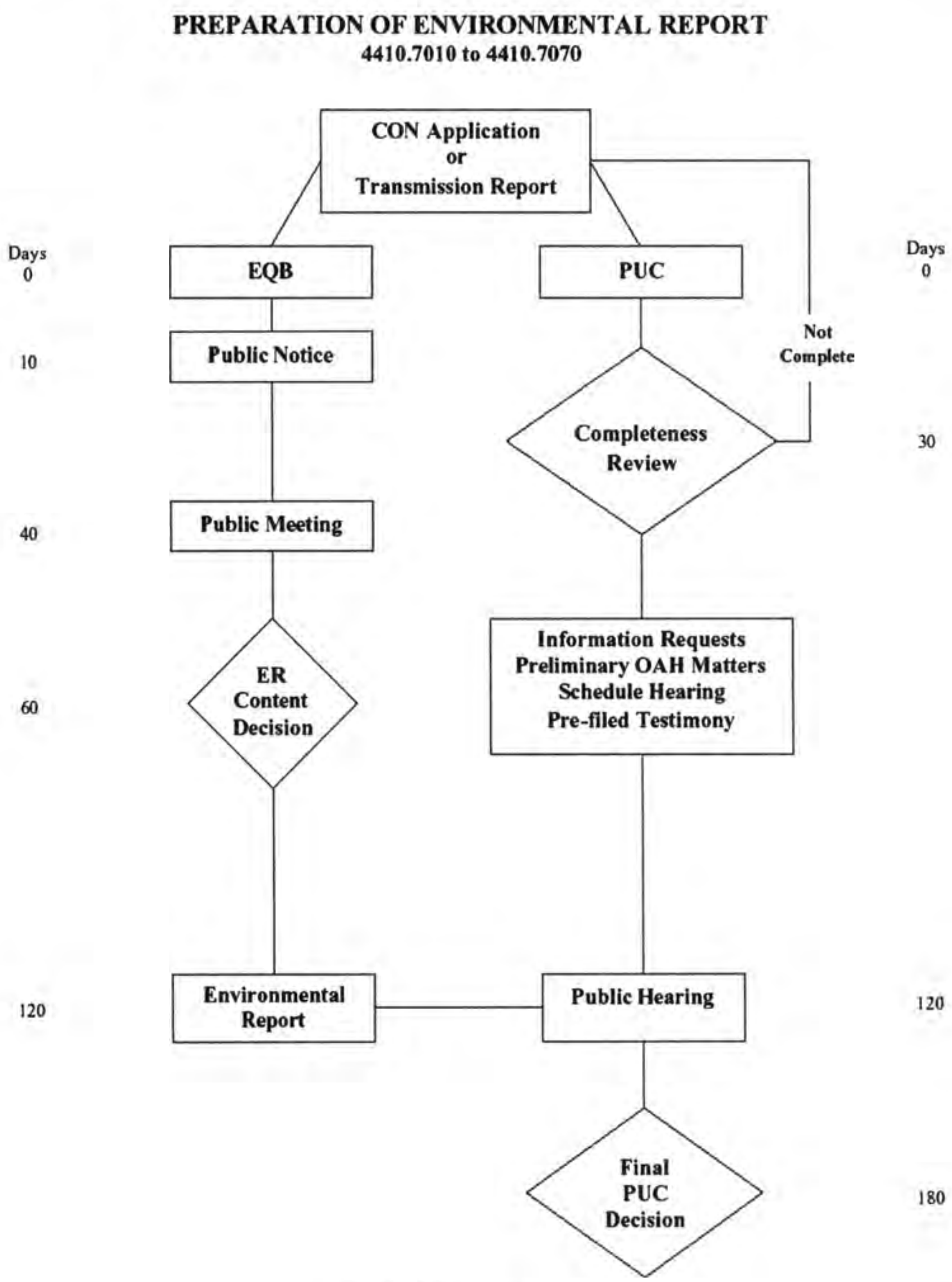

Fig. 4. PUC process diagram.

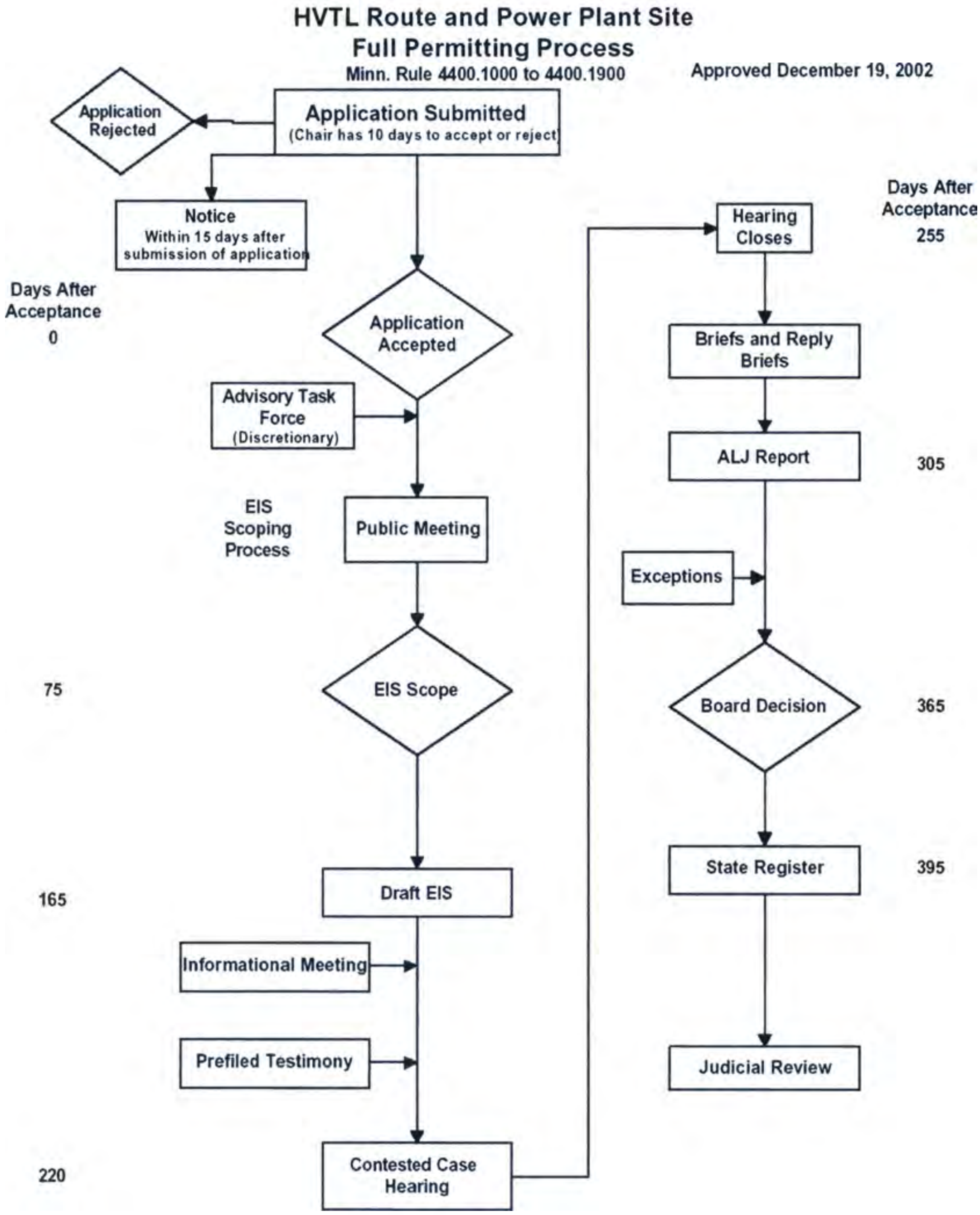

Fig. 5. Full review process diagram.

route application. After public review of the project, which may include a Citizens Advisory Task Force, the EQB drafts an Environmental Impacts Statement (EIS) based on the information gathered in the public meeting and the information in the route application. The Task Force's role is advisory and provides recommendations to the EQB on a specific issue with the project. The Route Permit is awarded approximately one year after application acceptance. The figure below identifies this process in greater detail.

2. Alternative Process: In this process, the utility is only required to identify one route for the application to the EQB. It follows a similar review process as the Full Review, however, the document produced by the EQB is an Environmental Assessment (EA). The process is much shorter, with a Route Permit awarded approximately six months following application acceptance. Fig. 6 identifies this process in greater detail.

MAJOR PROJECT DESCRIPTIONS

Lakefield Junction Substation to Fox Lake Substation 161 kV line

Xcel Energy submitted the first EQB route application in November 2003 for this project. The route permit

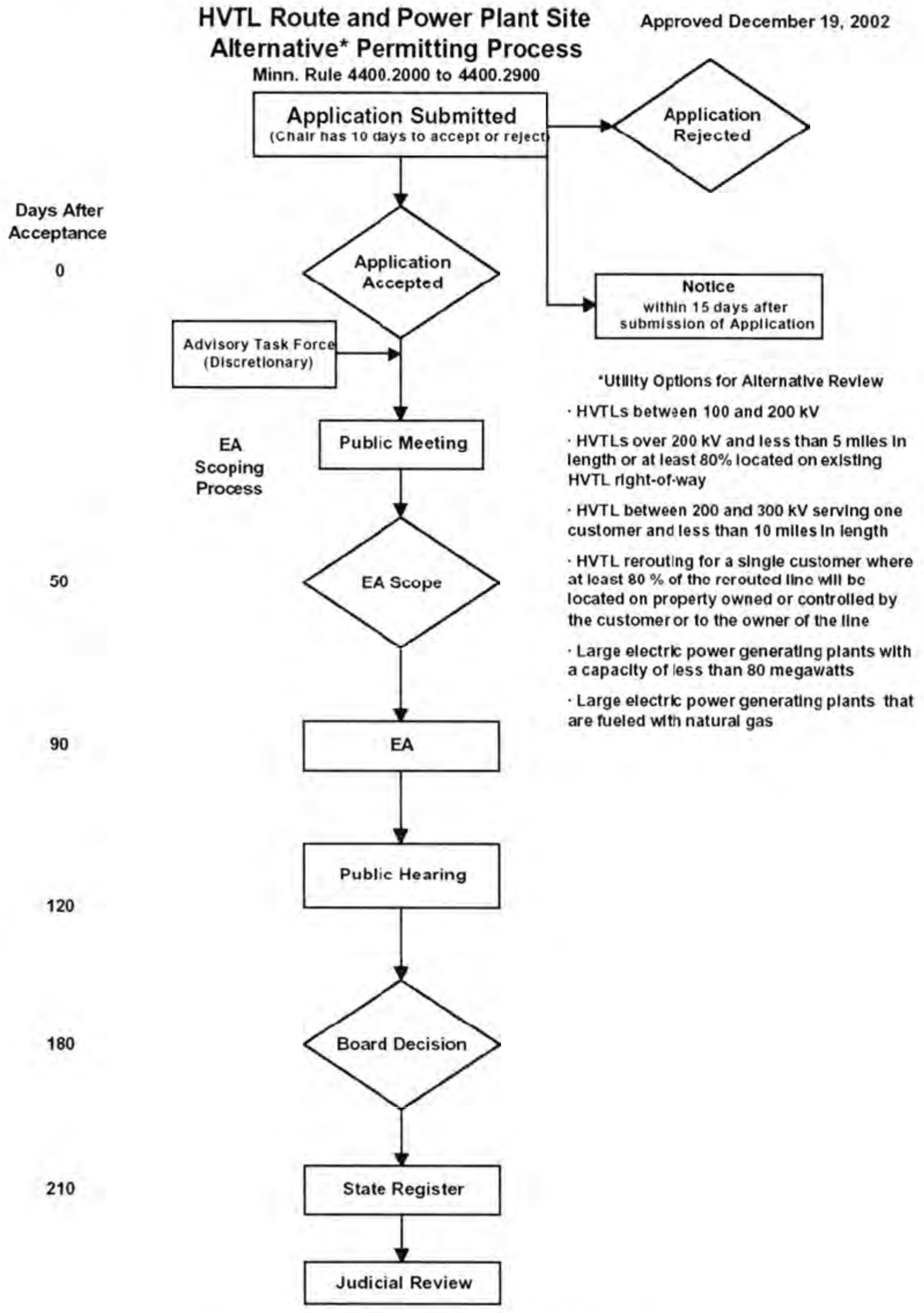

Fig. 6. Alternative review process diagram.

was filed under the EQB's alternative process. The route proposed is approximately 25 miles long and generally follows Interstate 90 (I-90) between Lakefield and Sherburn, Minnesota (Fig. 7).

The permit is expected to be issued in September 2004. Construction is expected to begin August 2005, with an in-service date scheduled for July 2006. Once this project is complete, the existing transmission capacity in the area will increase from 260 MW to 425 MW.

Split Rock Substation to Lakefield Junction Substation 345 kV transmission line

Xcel Energy's second route permit application was filed on April 30, 2004, for a 90-mile 345 kV transmission line from Xcel Energy's Split Rock Substation near Brandon, South Dakota, and Alliant Energy's Lakefield Junction Substation near Lakefield, Minnesota.

This project was filed under the Full Permitting Process, since the transmission line is greater than 200 kV. Two route alternatives were filed. The pre-

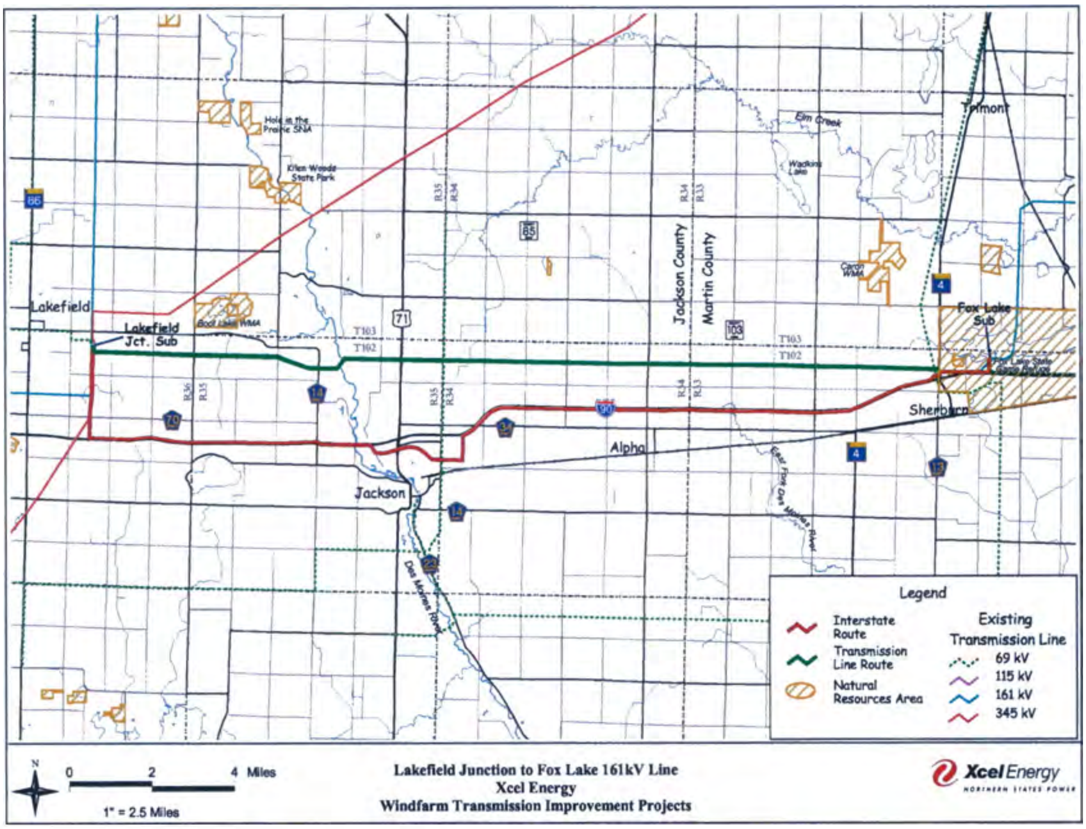

Fig. 7. Lakefield Junction to Fox Lake route.

ferred route generally follows I-90 for a majority of its length, with a slight divergence around the city of Worthington to connect with the new Nobles County Substation and to avoid the Worthington Municipal Airport. The alternative evaluated is located approximately three miles north of the I-90 route and follows several existing 161 kV transmission lines for the majority of its route. Xcel Energy would double circuit the 345 kV transmission line with the existing 161 kV lines along the final approved route. Fig. 8 identifies the two routes proposed.

The EQB decision on Xcel Energy's Route Permit is expected by April 2005. The EQB is currently completing the scoping process and is using a Citizens Advisory Task Force to assist in recommending a location for the routes and a location for the Nobles County Substation. Construction is expected to begin in April 2006, with an in-service date of August 2007. Xcel Energy also requires permits for the South Dakota portion of the project and will file for a permit with the South Dakota Pubic Utilities Commission in 2005.

Nobles County Substation to Chanarambie Substation 115 kV transmission line and Nobles County Substation

Included in the application for the Split Rock to Lakefield Junction project are proposals for the construction of a new Nobles County Substation and a 115 kV line that is approximately 37 miles long between the new Nobles County Substation and the Chanarambie Substation.

The Nobles County Substation is proposed near the town of Reading, Minnesota, northwest of Worthington. Three sites are being evaluated for the project. Fifteen acres are required for the substation, but Xcel Energy will work to acquire a minimum of 40 to allow room for expansion and create a larger buffer area around the completed substation.

Two routes were proposed in the route application. Both routes (East and West) would follow existing highways, township roads, and county roads as the line travels northwest along the edge of Buffalo Ridge. Fig. 8 also identifies the three potential substation locations and the route alternatives for the 115 kV transmission line.

As stated above, the EQB decision for this application is expected by April 2005. Construction of the 115 kV transmission line and the substation is expected to commence in June 2006. Completion of the transmission line construction is expected in August 2007.

Buffalo Substation to White Substation 115 kV transmission line and Yankee Substation

Xcel Energy's final application to the EQB to meet the outlet capability needs of the area is for a 28-mile long 115 kV transmission line from Buffalo Ridge Substation, located near Lake Benton in Lincoln County, Minnesota, to the White Substation owned by Western Area Power Administration (WAPA) located south of Brookings in South Dakota. Xcel Energy filed the application for this project on August 10, 2004. Associated

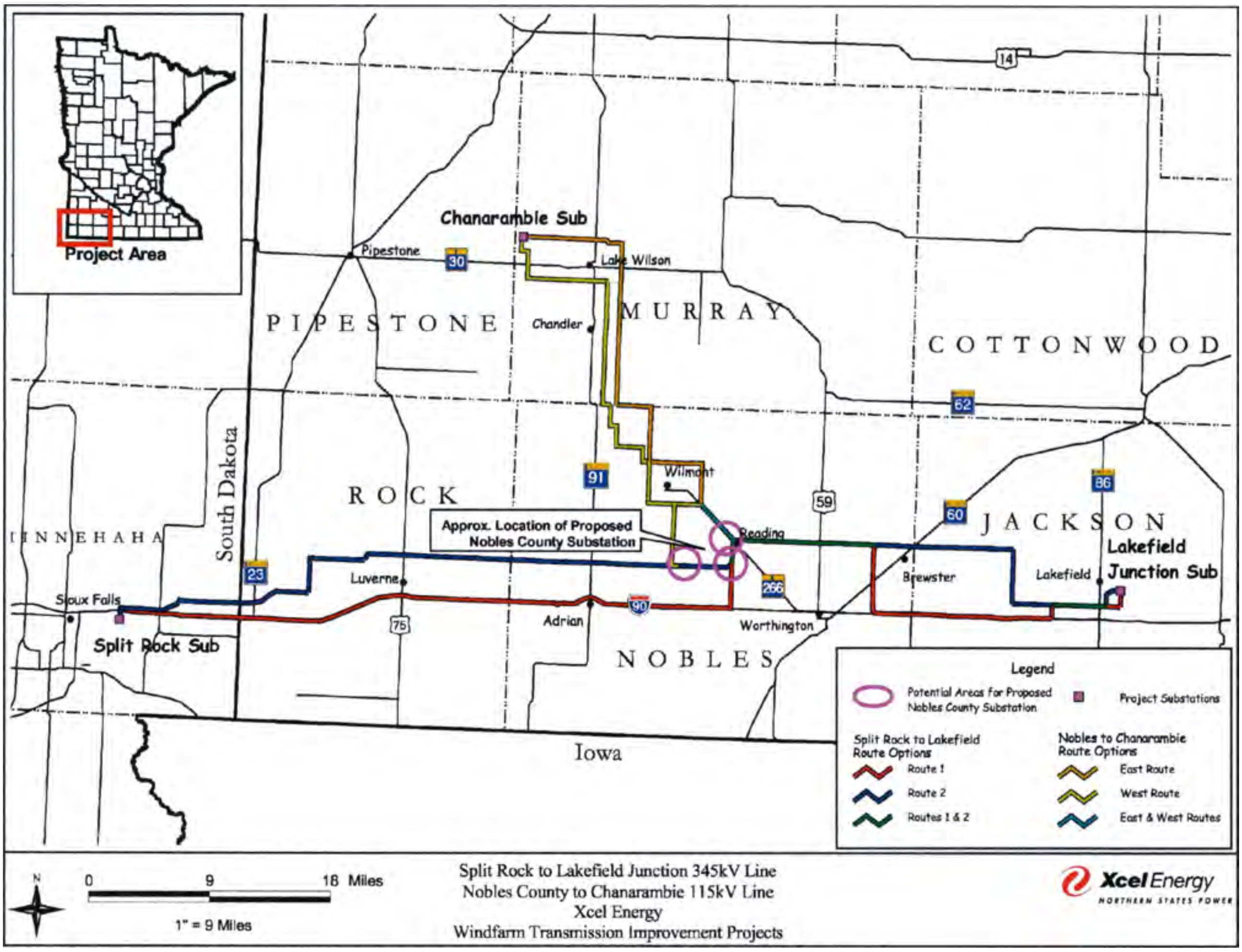

Fig. 8. Split Rock Substation to Lakefield Junction Substation route alternatives.

with the project is the new 115 kV/34.5 kV Yankee Substation that will be constructed midway along the new Buffalo Ridge to White Transmission line.

The Buffalo to White project will be filed under the alternative permitting process since the transmission line is between 100 and 200 kV. The Yankee Substation construction is also a part of the application, and five sites were evaluated as options for substation construction. Xcel Energy has evaluated several route alternatives in relation to the project. Several of these alternatives were rejected due to concerns with human and environmental impacts, cost or reliability. A single route was chosen from these options that generally follows state, county, and township roads northwest from Buffalo Ridge Substation toward the White Substation. There was one major siting issue for this project due to the need to avoid the Hole-in-the-Mountain resource areas. These areas are approximately 1,230 acres of native dry prairie (southwest) hill subtype habitat, which is a rather large portion of prairie in a State where only one percent of Minnesota's original 18 million acres of prairie remain. The proposed route will run adjacent to the Minnesota Department of Natural Resource's Hole-in-the-Mountain Wildlife Management Area and the Nature Conservancy's Hole-in-the-Mountain Prairie Preserve. Xcel Energy has proposed to remove a short section of its existing Minnesota Valley – Pipestone 115 kV line that currently bisects the DNR property.

The EQB Decision on the route permit is expected no later than February 2005. Construction is expected to begin in early 2006, with the transmission line coming on-line by March 2007.

PROJECT ISSUES

There are several key issues with each of these projects that the utility has either worked through at the public meetings during the route permit process or will continue to work on with the parties involved as the projects move forward into the design, construction, and permitting phases of the project. The key to identifying and solving these issues was upfront conversations with the public and agencies early in the process. Most of the issues that arose during the route permit process were common issues associated with conflicts in land use, however, there were other issues also unique to the project since it is interrelated to the outlet of wind energy generation. Table 1 summarizes the

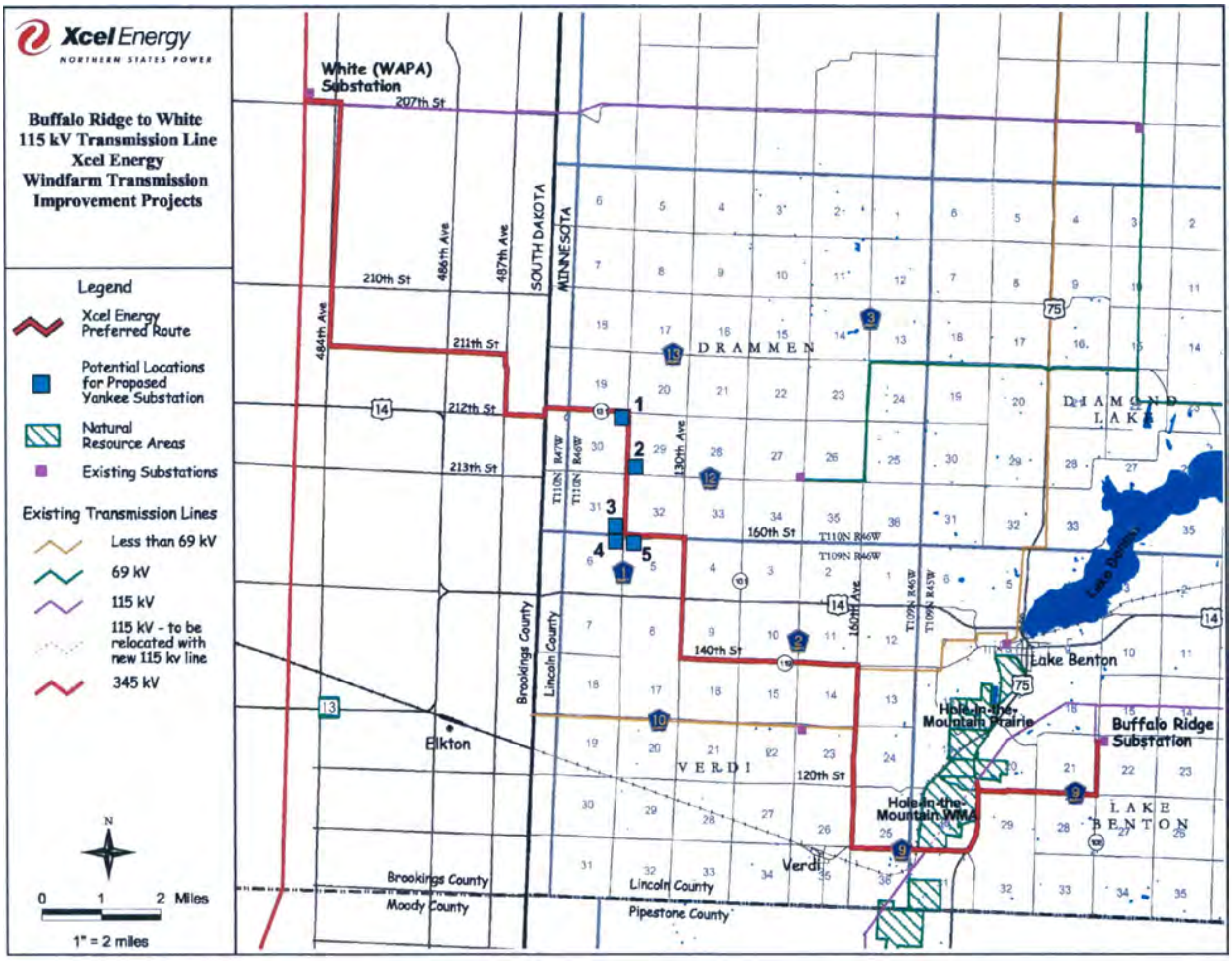

Fig. 9. Buffalo to White route alternatives.

unique issues for each project and notes how Xcel Energy addressed the issue.

AGENCY AND PUBLIC INVOLVEMENT

Through the course of developing the routes and applications for these projects, Xcel Energy has been successful in providing opportunities for interveners, agencies, and the public to provide input into the permitting process. Prior to the initiation of and during the permitting process, the project team worked with agencies and groups such as the Minnesota Department of Natural Resources, North American Water Office, Rural Minnesota Energy Task Force, Wind on the Wires, American Wind Energy Association, the Nature Conservancy, and a number of other local and national groups to develop support for the transmission line routes in a cooperative fashion. This has paved the way for support for the projects from the earliest stages of development.

PUC CON process

As stated previously, Xcel Energy agreed to study the need for additional transmission infrastructure in the Buffalo Ridge area during the approval of the merger of Northern States Power Company and New Centuries Energy to create Xcel Energy. A two-year transmission study, led by Xcel Energy and involving a number of utilities, the Mid-Continent Area Power Pool (MAPP) staff, and feedback from Minnesota regulatory staff, was completed in 2001. As a result of the Transmission Outlet Analysis (Study), it became clear that major infrastructure improvements were needed to provide more outlet capability. With the information obtained in the Study, Xcel Energy examined four different approaches/options to the transmission system development in support of wind in their application to the PUC for the CON. During the CON process, Xcel Energy met with and solicited input from several agencies and public interest groups as the projects moved forward. The primary agencies involved early in the process were the PUC, the Department of Commerce, and the Minnesota Environmental Quality Board. The public, various interest groups, and task forces formed, however, to help build the case for new transmission lines for wind energy, which included the Rural Minnesota Energy Task Force, Wind on the Wires, and North American Water Office.

As Xcel Energy developed its filing and case, and worked on its case with the PUC, the Company worked

Table 1. Major Southwest Minnesota transmission line projects – unique siting issues

Project	Issue	Resolution
General	Landowner payments for transmission line easements versus wind turbine easements. Wind generation companies pay landowners an annual fee that is likely larger than what a landowner will see for a 115 kV transmission line with an 80-foot easement on their land. Landowner compensation is a complicated field and in this case, landowners feel they deserve similar payments. In some cases, they have asked for consideration of payment of part of the profits from the wind generation.	The Company has been providing general information on this issue to educate the public about the difference between regulations that govern utilities versus wind developers, this issue needs to be addressed, however, outside of the routing process. It is a major policy issue with ramifications for all utilities.
	Small Wind: With the increasing focus on the development of "small wind" or wind farms owned by the local landowners, efforts were made in the CON process by several parties to address this issue. There is a concern regarding the ability of small developers having access to the wind outlet capability created by the new lines.	Xcel Energy worked closely with the small and large wind developers to ensure the substation siting supported both their needs. This issue has been complicated with several clarifications required from the PUC since larger developers were concerned about the impact on their projects.
	First major route permits filed under the new Minnesota rules. Extra time was required to work through the kinks in a new process.	Worked closely with the EQB to support their development of the EA/EIS in a timely fashion. Provided detailed information on the routes, environmental issues, mitigation measures and were willing to provide continuing support as the process moves forward.
	In the Upper Midwest, Xcel Energy generally builds projects in areas where vegetative cover includes a significant forest component. In the area of this project, trees are sparse and important to landowners for protection of their homesteads (groves). Clearing of trees is a concern.	Xcel Energy has committed to minimizing tree clearing by working to route the lines to avoid groves.
161 kV Lakefield Junction Substation to Fox Lake Substation	Recommendations to double circuit the new line with the existing Alliant Lakefield Junction to Fox Lake 161 kV transmission line. The existing Alliant Energy 161 line was key to maintaining reliability in region and taking it out of service would have incurred huge costs to the Company to provide backup generation during construction. Xcel specifically asked for a new line in the CON process to avoid taking this line out of service.	Double circuit not considered due to reliability and cost concerns. This is a special situation with this project since double circuiting is considered in many projects and often implemented.
345 kV Split Rock Substation to Lakefield Junction Substation	Schedule Impacts: There are two route options for the 345 kV project. One is primarily a new line, but the other incorporates a large amount of double circuit construction. If the double circuit option is selected, the construction timeline will be longer and will delay the in-service date for the project. This in turn delays the amount of generation that can be operated in the area. Generators may not be able to bring their projects on-line in a timely manner, and Xcel Energy may need to pay curtailment fees for generators it has contracts with that cannot generate.	The EQB will have to factor this into its final decision.
115 kV Nobles County Substation to Chanarambie Substation and Buffalo Ridge Substation to White Substation	Line Routing – "In My Backyard." For both of the 115 kV transmission lines, routing suggestions have been put forth to locate the line near landowners who want to develop wind and reduce their interconnection costs. In some cases, these routes are away from the main area where wind will develop, which would reduce efficiencies with interconnections.	Provide information on the routing criteria for these projects, which include the need to place the line and substations near Buffalo Ridge.
Nobles County and Yankee Substations	For both projects, several landowners have approached the company to sell their land. In addition, some landowners want the substation moved near them to improve their interconnection costs if they build wind turbines.	Xcel Energy will work with the interested landowners and purchase a site from a willing landowner that best suits the project. The substation site locations were based on the need to be near Buffalo Ridge and the ability to interconnect with existing and proposed transmission lines.

closely with the various interest groups to ensure that their major concerns regarding project need and scope were factored in to the process. Four options were under review. Each included different transmission line projects, ranging from rebuilds to new lines, so the pros and cons of each option were also discussed. One major issue that was discussed was the location of wind development on the ridge. Xcel Energy's preferred option did not include a project that helped address outlet for potential development of wind on the northern portion of Buffalo Ridge. After discussions with agencies and interveners on the issue, Xcel Energy's preferred option was modified to include a project that would support wind development in that area.

Intervener involvement

Often a utility will find itself arguing with many groups over which project should be approved by the regulators. Arguments are made that the utility is "overbuilding" the system, or there is "no need for the project" or "other solutions can avoid the need to build the transmission line." In this case, the majority of the parties supported the most robust option, which included the first major 345 kV transmission line in Minnesota in the 20 years. In the case of this project, Xcel Energy was faced with addressing concerns that the Company was not proposing facilities that would address all the needs and not working to build it fast enough.

Several of the Interveners in the case have usually been opponents to the Company. Interveners involved in this project include the Izaak Walton League of America, the American Wind Energy Association, the Minnesotans for an Energy Efficient Economy, the North American Water Office, Wind on the Wires, and the Rural Minnesota Energy Task Force.

The North American Water Office generally opposes Xcel Energy's continuing efforts to have nuclear and coal generation in the Company's generation portfolio. Past efforts of members of this group include opposition to the 400 DC line built in Minnesota in the 1970s. This group supports Xcel Energy's project for several reasons: 1) It supports the additional development of wind generation; 2) It believes these types of projects help the public by providing the infrastructure that will allow local people to build wind turbines and generate income.

Minnesota Environmental Quality Board Route Permit process

During the siting of the projects, the project team has worked closely with agencies and groups such as the MEQB, Minnesota Department of Natural Resources, Minnesota Department of Transportation, and local governmental groups to develop the transmission line routes in a cooperative fashion. This will help in addressing major issues during the preliminary siting of the lines and in reducing the issues to be brought forward during the MEQB routing process. The Minnesota Environmental Quality Board has held several town meetings, and a citizen task force was formed to provide public input on the proposed transmission line routes for the Lakefield to Fox Lake and Split Rock to Lakefield and Nobles to Chanarambie projects.

Public involvement and interaction

The public has been involved in the process of routing each of the transmission lines from very early on in the process. During the CON process, bulk mailings were sent out to the area announcing Xcel Energy's intention to build major lines in the area. Once the siting process began, meetings were held by Xcel Energy to gather information from the public on the proposed routes and substation sites. Web pages were made available for each project providing general project and contact information. Additional public meetings will be held as part of the required regulatory meetings during the permitting process.

Preliminary routes are provided on aerial maps at the public meetings to give the public an idea of the route location. Public and agency input provided route changes on several of the projects, as follows:

- Lakefield Junction to Fox Lake: Comments were provided on the initial route through Jackson, Minnesota, due to several plans for expansion by local businesses. Xcel Energy worked with the landowners and the City to develop alternatives to minimize impacts to all parties involved in its filing. The route was further refined during the route permit review process by the EQB Citizens Advisory Task Force. This resulted in a final route which was supported by all the major parties reviewing the route;
- Split Rock to Lakefield Junction: Route changes needed to be made for segments where the landowners had sold wind rights in the middle of those sections. As farms grow and population shifts in this area, many homesteads are abandoned. The public was helpful in identifying abandoned homes. Initially Xcel Energy proposed to build the 345 kV line adjacent to existing 161 kV transmission lines. Considerable concerns were raised by the public regarding the impacts this would have on their ability to maneuver around structures. Although more expensive, Xcel Energy has proposed to double circuit with adjacent structures if the selected route includes any existing transmission line corridors; and
- Buffalo to White: Based on comments received at public meetings, Xcel Energy made slight modifications to the route in South Dakota and rejected an alternative route segment.

The success of public meetings in this part of Minnesota was primarily due to the audience that we encountered. Southwest Minnesota typically is regarded as a congregation of rural communities, where having coffee and discussing issues face-to-face is expected. In many rural areas, people know each other in neighboring towns. Given the sparse population in this area, people know each other in neighboring counties. Getting to know the community through the various public meetings helped Xcel Energy communicate with the public. The utility relied primarily on the meetings in conjunction with mailings to get its message across. Using the internet and email is an effective and efficient way to communicate information to the public. Not relying solely on the internet and email, however, was an important aspect of communicating to the public about the project, since many people in this area do not have email or internet access.

In addition, a group called the Rural Minnesota Energy Task Force, drawn from thirteen counties in Southern Minnesota, formed to provide policy guidance on issues surrounding energy development in the region. Originally formed in 1996 as the Ridge Counties Task Force, it developed into the Wind Task Force and then into the SW Minnesota Energy Task Force and finally to its current name, as both membership and policy issues have expanded. Since it is composed of local leaders and has been involved in the permitting process for these projects from the beginning, the Task Force has been helpful in providing data to the public.

Unusual/atypical reactions

Since the suite of projects is being built to accommodate the wind development on the ridge, several of the issues brought up during public meetings were different than those the utility is used to addressing.

Some of the comments received via mail or email or heard at the public meetings included the following:

- "I'm willing to sell some land for a substation. Give me a call."
- "What's taking so long? Why don't you know where the transmission line will be yet?"
- "Why do you have to route the transmission line? Just build it."
- "Route the line by me so that you can site the substation by me."
- "I think the substation should be nearer to our property."
- "What do you do if more than one person wants to sell you their land?"
- "It is not fair that you are siting the substation and line over there, please put it by us—we have a higher potential for wind on our land."

One of the more common issues that people bring up at public meetings is not wanting the transmission line on their property, which is referred to as "Not In My Backyard" (NIMBY). While some people did not want the transmission line on their land, several people actually asked for the transmission line or substation to be placed on their land. The reason was primarily because many of the landowners believe that if the transmission line is closer to their land, the cost of developing a wind farm would be less than if the lines were farther away. In reality this may not make a difference since the wind projects do not tie directly to the transmission lines under review, but instead to the 34.5 kV system (called "feeder lines"). Placing the substation on or near their land, however, would decrease the interconnection costs. Additionally, in some cases Xcel Energy will be able to build the lines capable of supporting the 34.5 kV feeder lines, which could decrease interconnection costs.

The additional support of lines will allow additional projects where people see another benefit in addition to the use of power. The benefit to the local economy encourages governmental and political support as well as landowner support.

PROJECT LESSONS

The transmission line projects in southwest Minnesota have unprecedented support from landowners and local governments compared to other projects Xcel Energy has worked on in Minnesota. The support is the result of several factors, including public support for wind generation and the methods Xcel Energy used to provide information to the public during the need and the route permit processes. Overall, the process has been open to public and agency comments, which in turn have led to an evolution of projects and routes that are favorable to a majority of the public.

Currently, the entire suite of projects is expected to be in-service by the fall of 2007. No major issues are anticipated that would delay the permits. It is assumed that once these facilities are completed, additional infrastructure will be required, since the wind industry continues to grow in the region. Midwest Independent System Operator (MISO) and other groups are working to start the transmission planning process to address this need. What has clearly been learned by these projects is that the public and interveners will strongly support the need to build infrastructure if they understand the projects and the need for them. The regulatory processes and public outreach by Xcel Energy has helped to educate people, but the primary way they understand is by seeing the improvement that the projects are providing to their areas. As stated in an earlier section, wind development has helped to improve the overall economy of the area through increased jobs, businesses, and infrastructure that increases the tax base. Key lessons learned include the following:

- People will support projects if they understand the need for a project. We need to take the lessons from these projects and translate them into methods to help support other transmission line projects that don't have wind directly tied to them. Education of the public on the importance of electricity to their everyday life and how transmission lines and substations support that need is vitally important;

- People will support projects where they see a direct benefit to them or their local economy;
- As many utilities know, early meetings allow people to learn, to ask questions, and to provide input, which is key to gathering support;
- Working with various agencies and special interest groups early on in the process helps to develop the needed support for a project. More work needs to be done for other major projects to bring in major groups and businesses that support the infrastructure needed;
- Public meetings and face-to-face contact are still essential for good communication with landowners. The internet and email can help reduce some costs, but cannot replace that personal dialogue;

Cautions:

- It is not Utopia. Issues such as EMF and NIMBY still arise, although at a lesser degree;
- New issues have emerged, such as questions regarding the differences in easement payments between wind turbines and transmission lines. Landowner compensation has become an issue, since the payments to a landowner for hosting a wind turbine versus a transmission line are calculated differently. It is challenging to educate people on the difference between a regulated utility and a business building wind turbines. The need for eminent domain is still important, and the requirement to build projects for the public good needs to be clearly explained; and
- Education on how the transmission grid works is still important. Information needs to be conveyed on how the generation that is carried on the lines does benefit everyone.

CONCLUSIONS

Success on this project has been unique due to support for wind development, which translated into support for the transmission infrastructure. People will support projects where they see a distinct benefit to themselves. We need to explore ways to educate people. Their ability to turn on a switch is a benefit.

Once the need is understood, other issues surface that are not normally on the radar or ever considered. Xcel Energy will continue to address several of the issues, including the ROW valuation. This has become a large issue in the region because of the discrepancies in easement payment. A distinction between private developers and regulated utilities needs to be made, and Xcel Energy will need to be proactive in educating the public on these issues. The success of the public meetings can likely be used as a model for this issue.

Xcel Energy will continue to use this model on powerline projects by getting groups involved early, educating the public on the need for infrastructure, and assessing ways the projects benefit the people affected by the infrastructure in the field. This will be incorporated into the public open houses, agency meetings, and face-to-face interactions that have become standard practice.

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REFERENCES

Minnesota Department of Employment and Economic Development. 2001. Regional Spotlight: Southwest Minnesota. http://www.deed.state.mn.us/lmi/publications/review/0401/0401rs.htm.

Minnesota Department of Natural Resources. 2004. Recreation Compass: Hole-in-the-Mountain WMA. http://www.dnr.state.mn.us/maps/compass.html?map=COMPASS_MAPFILE&mode=indexquery&shapeindex=217&qlayer=wmabdpy3_query.

Minnesota Environmental Quality Board. 2003. HVTL Route and Power Plant Site Full Permitting Process Diagram. Minnesota Department of Administration. http://www.eqb.state.mn.us/pdf/2003/Fullpermitprocessfinal.pdf.

Minnesota Environmental Quality Board. 2003. HVTL Route and Power Plant Site Alternative Permitting Process Diagram. Minnesota Department of Administration. http://www.eqb.state.mn.us/pdf/2003/Altpermitprocessfinal.pdf.

The Minnesota Project, Windustry, Southwest Regional Development Commission. 2003. The Facts on Wind: A Proven Economic Development Tool. http://www.deed.state.mn.us/lmi/publications/review/0401/0401rs.htm.

Minnesota Public Utilities Commission. 2004. Preparation of Environmental Report Diagram. http://www.eqb.state.mn.us/pdf/FileRegister/rules4410/4410CONSchematic.pdf.

National Agricultural Statistics Service. 2002. County Profile: Jackson, Lincoln, Martin, Murray, Nobles, Pipestone, Rock Counties Minnesota. 2002 Census of Agriculture, U.S. Department of Agriculture, Minnesota Agricultural Statistics Service. http://www.nass.usda.gov/census/census02/profiles/mn/cp27063.pdf. http://www.nass.usda.gov/census/census02/profiles/mn/cp27133.pdf.

The Nature Conservancy. 2004. Hole-in-the-Mountain Prairie. http://nature.org/wherewework/northamerica/states/minnesota/preserves/art7109.html.

Northwest Economic Associates. 2003. Assessing the Economic Development Impacts of Wind Power. Prepared for the National Wind Coordinating Committee. http://www.nationalwind.org/pubs/economic/econ_final_report.pdf.

Union of Concerned Scientists. 2004. Farming the Wind: Wind Power and Agriculture. http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=128.

Wind Powering America. 2004. Electricity from the Wind: Economic Development for Rural Communities. http://www.eere.energy.gov/windpoweringamerica/docs/economic_development.doc.

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When Public Convenience and Necessity Are Not Enough: Who Is Deciding Whether, Where, and How to Build Natural Gas Pipelines?

Elizabeth N. Dolezal, Fran Lowell, and Todd A. Mattson

Receiving Federal Energy Regulatory Commission or state utility commission authorizations that convey the power of eminent domain has historically provided utility companies in the United States with some assurance that natural gas pipelines could be built in a timely and financially predictable manner. Recent projects have called this concept into question. In implementing their environmental regulations, other federal and state agencies, possessing limited authority over natural gas pipelines, have delayed projects that have already been determined to be in the public interest and received certificates of public convenience and necessity. As a result of conflicting or overlapping agency objectives and priorities, project applicants have experienced lengthy reanalysis of a project's purpose and need, routing alternatives, and environmental impacts. Resulting delays and environmental permit conditions have significantly increased costs, jeopardized delivery contracts, and in some cases, resulted in project cancellation. Case studies of the Islander East, We Energies, and Georgia Strait Crossing pipeline projects provide specific details on the economic and regulatory impacts resulting from this phenomenon. The implications of conflicting environmental regulatory review and insufficient agency coordination, and the steps being taken to avoid scenarios such as those presented in the case studies are also discussed.

Keywords: Federal Energy Regulatory Commission, State Utility Commissions, eminent domain, public convenience, routing alternatives, pre-filing process, agency coordination, Islander East Pipeline Project, We Energies Pipeline Project, GSX Pipeline Project, ROW

INTRODUCTION

Sponsors of proposed natural gas pipelines typically need a Certificate of Public Convenience and Necessity (Certificate) from either the Federal Energy Regulatory Commission (FERC) for interstate pipelines, or the state public service or utility commission for intrastate pipelines. The Certificate provides overall authority to construct the pipeline, approves the route and construction methods, and typically conveys the right of eminent domain for the project, allowing the project sponsors to obtain property easements through condemnation.

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

Until recently, receipt of a Certificate was timed to occur just prior to the initiation of construction. It was assumed that other permits and approvals would be issued following issuance of a Certificate promptly without much controversy. This assumption has become less reliable as state agencies have increasingly been in conflict with the certification process and have used their state permitting authority or federally delegated authority (*e.g.*, under the Clean Water Act (CWA) or Coastal Zone Management Act (CZMA) programs) to alter, slow, or even block certificated projects. Jurisdictional conflict or ambiguity has increased the complexity of planning natural gas pipeline projects. Holders of federal Certificates have the ability to pre-empt state and local permits that may prevent the project from moving forward, but are generally hesitant to exercise this option. The federal pre-emption authority can effectively reduce risk of significant project delays and associated cost increases and/or uncertainty in the ability to develop the project, however, the preemption option is not available for federal programs under the CWA and CZMA that are delegated to the states.

The federal certification process enables the FERC to take a national-level approach to the siting and construction of necessary natural gas infrastructure. Certification of intrastate projects through the state public service or utility commissions allows for a statewide approach. Conversely, in many cases, project opposition is based primarily on local issues such as perceived lack of benefit to towns affected by a "pass through" project. Increasingly, local concerns are complicating or derailing federal- or state-level permitting programs and delaying the construction of certificated natural gas pipeline projects.

This paper presents case studies of three projects across the United States (*i.e.*, Washington, Wisconsin, and Connecticut/New York). All three projects received Certificates. Construction of one of the projects was delayed a year, construction of the other two is still pending. Our purpose is not to criticize any company or agency, but to share experience for the benefit of planners and regulators of future projects.

CASE STUDIES

Georgia Strait Crossing Project

Project overview

Georgia Strait Crossing Pipeline LP (GSX-US) proposed to construct and operate a 47-mile-long natural gas pipeline from the Canadian border near Sumas, Washington, to the United States–Canada border at Boundary Pass in the Strait of Georgia, where it would connect with its Canadian counterpart (GSX-Canada) and continue on to Vancouver Island, British Columbia. Both pipelines are joint undertakings of Williams Gas Pipeline Company and British Columbia Hydro and Power Authority (BC Hydro). The Georgia Strait Crossing (GSX) pipeline was proposed to provide an additional source of natural gas to Vancouver Island.

Certification process

In April 2001, the project sponsors filed an application with the FERC, which in turn began the process of preparing an Environmental Impact Statement (EIS) to satisfy the requirements of the National Environmental Policy Act (NEPA). State and federal agencies were invited to participate in the process. The U.S. Army Corps of Engineers (COE) was the only agency that elected to be a cooperating agency, although the other agencies reserved the right to comment on the EIS. The project was controversial for three reasons: First, the project did not deliver gas to Washington state but rather to Vancouver Island; second, a recent gasoline pipeline explosion in the nearby City of Bellingham had increased citizen concern about pipeline safety; and finally, the project had the potential to affect some sensitive environmental resources such as salmon streams and an offshore aquatic reserve. One of the counties crossed by the route passed a moratorium on issuing any permits for pipeline projects.

As the NEPA process progressed, various agencies and the public provided comments on the draft EIS. These comments were considered in the final EIS, which was published in July 2002. The FERC issued a Certificate for the GSX project on September 20, 2002. The Certificate included 34 environmental conditions that GSX-US was required to implement to avoid or minimize environmental impacts.

Post-certificate issues

After obtaining the FERC Certificate, GSX-US initiated efforts to comply with the conditions of the FERC Certificate as well as continued its efforts to obtain other federal, state, and local permits. Prior to obtaining any state or local permits or approvals, the project was required to undergo a State Environmental Policy Act (SEPA) review. For this project, the Washington Department of Ecology (WDOE) was the lead state agency responsible for implementing SEPA as well as issuing CWA water quality certification and determining CZMA consistency. Although SEPA implementing guidelines encourage agencies to coordinate and issue EISs that satisfy the requirements of both SEPA and NEPA (WDOE, 1998), the WDOE did not elect to cooperate with the FERC in the preparation of the FERC's EIS and ultimately found the FERC's EIS did not satisfy its SEPA requirements. In July 2003, WDOE issued a list of deficiencies in the EIS that would need to be addressed in order to complete the SEPA process. WDOE used a third-party contractor to prepare a supplemental EIS based on information provided by GSX-US. The final supplemental EIS was issued in January 2004.

Project milestones

The timeline from when GSX-US announced the project to when WDOE issued its final supplemental EIS is summarized below.

- September 29, 1999 - GSX-US announces the project to the public and begins consulting with the regulatory agencies;
- April 24, 2001 - GSX-US files an application for a Certificate of Public Convenience and Necessity with the FERC;
- June 1, 2001 - FERC issues a Notice of Intent to prepare an EIS under the National Environmental Policy Act (NEPA). State and federal agencies were invited to cooperate in the preparation of the EIS;
- October 11, 2001 - GSX-US amends its application to reflect a new location for its compressor station and pipeline route variations;
- December 10, 2001 - FERC issues a draft EIS for public and agency review and accepted comments until February 26, 2002;

- July 17, 2002 - FERC issues a final EIS for the GSX-US project;
- December 2002 - WDOE initiates a process to evaluate whether the final EIS issued by the FERC would meet the environmental review requirements under SEPA;
- July 28, 2003 - WDOE issues a list of 39 issues that would need to be addressed in a supplemental SEPA document;
- September 24, 2003 - WDOE issues a draft supplemental EIS for public and agency review; and
- January 19, 2004 - WDOE issues a final supplemental EIS for the GSX-US project.

Recent developments

In addition to its efforts to assist the WDOE in complying with SEPA and obtain its necessary authorizations from the FERC, GSX-US also pursued obtaining CWA and CZMA approvals. The company began by seeking a CZMA consistency determination in May 2001 and CWA water quality certification in July 2001. In the case of its CZMA application, GSX-US apparently failed to include a request for a shoreline permit and other documentation in its initial application. According to GSX-US, however, the WDOE only notified GSX-US of the missing information 20 months after the application was filed rather than within the 30 days required under Washington State's coastal zone management regulations. Similarly, although required to respond within one year of GSX-US' CWA application, the WDOE did not respond for two years. In April 2004, the FERC issued a declaratory order that the WDOE had waived its jurisdiction under the CWA and CZMA with respect to the GSX project based on the WDOE's failure to act within mandated timeframes.

The WDOE requested a rehearing of the FERC's April order. The WDOE did not dispute that it had failed to give GSX-US the proper notification, but argued that the FERC "improperly" granted the company a Certificate and presidential permit before receiving both CWA and CZMA certifications from Washington State. Further, the WDOE claimed that the FERC's authorizations "erroneously preempted" the requirements of both the CWA and CZMA. On July 7, 2004, the FERC upheld its order. The FERC's responses to the WDOE included the following:

- conditions to its Certificate that GSX-US must meet the federal permitting requirements of, among other things, both the CWA and CZMA, GSX-US could not exercise its certificate authority and begin construction without first receiving authorization from WDOE;
- if the WDOE disagreed with FERC's decision, it had 30 days after the FERC issued its final decision to challenge or request rehearing of the order (which it did not); and
- the assertion that the FERC should have withheld its approval of the project until GSX-US had its CWA and CZMA certifications in hand was a "collateral attack" on the FERC's authority over the project.

After the FERC's July 7 finding, the WDOE began pursuing legal action against the FERC regarding its CWA and CZMA finding. Due in part to the arguments surrounding the CWA water quality certification, the COE has not issued its federal permit for the project. As of the date this paper was written, no resolution on the legal and permitting issues has been reached for GSX-US' project. As of June 2004, another proposal has been announced to provide additional natural gas to Vancouver Island (British Columbia Utilities Commission, 2004).

EDITORS NOTE: On December 20, 2004, Williams announced it would discontinue development of the GSX project.

We Energies Project

Project overview

In November 1999, Wisconsin Gas Company (WGC, doing business as We Energies), filed an application with the Public Service Commission of Wisconsin (PSCW) for authority to construct and operate a new 34-mile-long natural gas pipeline in southeast Wisconsin. The purpose of the project, referred to as the Ixonia Lateral Project (Lateral), was to connect We Energies' existing gas distribution facilities in the Milwaukee area to the Guardian Pipeline system. Guardian Pipeline, L.L.C. filed an application with the FERC at approximately the same time to construct the Guardian Pipeline, which would provide new transportation services from the Chicago Hub near Joliet, Illinois and interconnect with the We Energies system in Wisconsin. In its initial application, We Energies anticipated that the in-service date for the Lateral would be November 2002.

Project certification

As the lead state permitting agency for the Lateral project, the PSCW was responsible for conducting an environmental analysis in compliance with the Wisconsin Environmental Policy Act (WEPA), which would include the preparation of an EIS. The FERC, which was preparing an EIS for the Guardian Pipeline project during the same time period, considered the Lateral project to be an integral component of the Guardian Pipeline project, and therefore included the Lateral project in its environmental review. In light of the close connection between the two projects, the PSCW agreed to cooperate with the FERC in the preparation of the portion of the Guardian Pipeline EIS that would address the Lateral project rather than preparing a separate EIS for the Lateral project. The Wisconsin Department of Natural Resources (WDNR) was also a cooperating agency in this process.

We Energies' initial application included four route segments for PSCW consideration that could be combined into two alternative pipeline routes. Based on its ongoing analysis and input from landowners, agencies, and other interested parties, We Energies also submitted several supplemental filings between January 2000 and February 2001 containing additional route alternatives and variations. At the direction of the PSCW, We Energies did not initially specify a preferred route. In June 2000, however, We Energies identified its recommended route, recognizing that the final route would be determined by the PSCW. We Energies' recommended route reflected We Energies' consultations with affected landowners and their neighbors to address concerns about impacts on agricultural land, future development, and other issues. Although the recommended route had the advantage of minimizing certain agricultural impacts and satisfying several landowners' concerns, it also involved routing the pipeline through several wetlands.

A southeast-Wisconsin-based opposition group called Neighbors Standing United (NSU) was active throughout the PSCW's environmental review process. The group disagreed that there was a need for the Lateral project, and expressed concerns about impacts on landowners, agriculture, and the environment. NSU and other project opponents participated in the joint FERC and PSCW public scoping and public comment meetings held during the preparation of the EIS, and intervened and testified in PSCW public hearings on the Final EIS.

In July 2001, the PSCW issued its Final Decision authorizing We Energies to construct and operate the Lateral project and identifying a final approved route. The approved route was the same as We Energies' recommended route. The PSCW stated in its Final Decision, "The Commission compared route segment and variation choices based on environmental, landowner, land use and development, safety, and engineering considerations. WGC's recommended route best balances these considerations." NSU continued to actively oppose the project after the PSCW issued its Final Decision and filed a petition for judicial review of the PSCW Final Decision, which was denied by the County Circuit Court in November 2002.

Post-certificate issues

Once the PSCW issued its Final Decision identifying the pipeline route, We Energies was able to complete and submit applications for other federal, state, and local permits that could not be applied for until the final route was known. Among the required permits and approvals were authorizations from the WDNR for several activities, including wetland and waterbody crossings, construction stormwater management, and hydrostatic test water discharges. In Wisconsin, the required state authorizations for wetland and waterbody crossings, which are subject to several WDNR regulations, are referred to comprehensively as a "Chapter 30 Permit." In September 2001, the Company submitted its Chapter 30 Permit application to the WDNR.

The WDNR initially anticipated that it would be able to issue a Chapter 30 decision by March 2002 to allow We Energies to construct the project on schedule and meet its planned in-service date. In February 2002, however, the WDNR indicated that the permit would be delayed due to recent legal action that NSU had taken against the WDNR to challenge the WDNR's permitting of the Guardian project. Although the WDNR was not legally prohibited from proceeding with its permitting of the Lateral project, We Energies and the WDNR mutually agreed to collaborate in developing Chapter 30 permit conditions that would be satisfactory for all stakeholders. Throughout the remainder of 2002, We Energies conducted additional studies and provided numerous application supplements at the request of the WDNR. Several meetings were held to discuss the supplemental information, potential route modifications, routing constraints, and mitigation measures, particularly related to wetland impacts. We Energies delayed construction of the Lateral until a firm date for issuance of the Chapter 30 permit could be established. Meanwhile construction of the Guardian pipeline began even though the We Energies Lateral would not be able to provide the planned take-away capacity and accept the volume of gas that the Guardian pipeline was intended to provide.

In October 2003, We Energies and the WDNR met with project objectors, including representatives from NSU, the Waukesha County Environmental League, and the Wisconsin Wetlands Association (WWA, an environmental advocacy group). NSU and the WWA became active participants in the Chapter 30 permitting negotiations. After a lengthy process, the WDNR, We Energies, NSU, WWA, and other parties stipulated to the issuance of the Chapter 30 permit in January 2003. The outcome of the negotiations included a number of route changes and the expanded use of horizontal directional drilling (HDD) to avoid wetland impacts. We Energies agreed to fund third-party monitors that would be on site during construction and report directly to the WDNR. We Energies also agreed to implement expanded wetland restoration measures and undertake a long-term monitoring program for wetlands affected by construction.

The route modifications, revised construction measures, and associated cost increases resulting from the Chapter 30 permitting process had to be reviewed and approved by the PSCW, which issued an Amended Final Decision in April 2003. The final approved cost of the project was \$97.5 million, which represented a \$35.5 million increase over the originally approved project cost of \$62 million. In its Amended Final Decision, the PSCW noted that, in large part, the cost increase reflected agreements We Energies made with the WDNR and others during the WDNR permitting process for wetland and waterbody crossings. Construction was completed by late 2003, and the Lateral was placed into service in December 2003, about one year later than originally planned.

The difficulties that occurred during the permitting of the We Energies Ixonia Lateral were the direct result of a conflict between the respective regulatory missions of the PSCW and the WDNR as illustrated by the following:

- The PSCW is required to consider a wider range of factors than WDNR, including other land uses such as agriculture. The PSCW's decision compared route/variation options based on environmental, landowner, land use and development, safety, and engineering considerations. The PSCW also attempted to maximize collocation with existing linear facilities and to route along property lines to reduce impacts on present land uses and future development;
- The PSCW authorized a route that crossed several wetlands in an effort to balance multiple concerns (*e.g.*, agriculture, future development, minimizing property owners, making use of property lines). The PSCW determined that application of We Energies' Wetland and Waterbody Construction and Mitigation Procedures should substantially protect the integrity of waterbodies and wetlands crossed by the project; and
- The WDNR's obligation under Wisconsin law requires that the agency's priority be to consider "Practicable Alternatives" in an effort to maximize the avoidance of wetlands and minimize wetland impacts. Practicable Alternatives are defined as those alternatives that are, "available and capable of being implemented after taking into consideration cost, available technology and logistics in light of overall project purposes." The WDNR does not consider other factors such as other land uses or landowner concerns (*e.g.*, agriculture).

Project milestones

The following summarizes the milestones between the time We Energies submitted its PSCW application and the time the Lateral pipeline was placed in service:

- November 30, 1999 - We Energies files it application with the PSCW;
- July 25, 2001 - PSCW issues its Final Decision authorizing the Lateral Project;
- September 28, 2001 - We Energies submits its Chapter 30 Permit application to the WDNR; WDNR anticipated issuing a decision by March 2002;
- February 2002 - WDNR notifies We Energies that the Chapter 30 Permit would be delayed pending additional analysis;
- March 2002 – January 2003 - We Energies provides additional environmental studies and application supplements to the WDNR; We Energies, the WDNR, and project opponents conducted extensive negotiations on the pipeline route, environmental mitigation measures, and Chapter 30 permit conditions;
- January 15, 2003 - WDNR issues a Chapter 30 Permit for the Lateral Project;
- February 14, 2003 - We Energies files updated information with the PSCW concerning the project design, cost, location, construction practices, schedule, and cost effectiveness analysis;
- April 1, 2003 - PSCW issues its Amended Final Decision;
- May – December 2003 - We Energies constructs the Lateral Project; and
- December 2003 - We Energies places the Lateral pipeline in service.

Recent developments

The regulatory inconsistencies experienced during permitting of the Lateral project were a major obstacle for project planning and resulted in a significant delay and increased cost of the Ixonia Lateral. In comments published by the Business Journal of Milwaukee, one of the PSCW Commissioners expressed his frustration with the regulatory situation, stating, "My concern is not with the DNR's ultimate goal of reducing the project's impact on wetlands but the length of time and costs to ratepayers needed to achieve our mutual objective." (The Business Journal of Milwaukee, 2003). To address this situation, the Governor of Wisconsin issued an executive order directing the PSCW and the WDNR to develop a streamlined process for reviewing energy projects. The PSCW and the WDNR entered into a cooperative agreement that, in its Statement of Purpose, states, "The goal of this agreement ... is to ensure that the review of proposed energy construction projects ... proceeds in a timely and efficient manner that assures that energy needs are met and environmental protection is achieved consistent with our respective agency regulatory authorities."

As an outcome of this agreement, Wisconsin recently enacted legislation (2003 Wisconsin Act 89) that establishes a dedicated energy group within WDNR to participate fully in the PSCW review of pipeline projects and to issue Chapter 30 permits. The goal of this program is to identify the WDNR's issues early in the review process so they can be reflected in the PSCW certificate. The new process will likely increase the duration of the certification process and requires more detailed information in the initial application. The new process, however, provides for simultaneous rather than sequential agency reviews, and requires the WDNR to issue its Chapter 30 permit (as well as certain authorizations delegated to the state under the CWA) within 30 days of the issuance of the PSCW decision. In a separate but related effort, Wisconsin enacted certain regulatory reforms (2003 Wisconsin Act 118, or the Jobs Creation Act), which among other reforms, is intended to clarify and streamline the Chapter 30 process. No major pipeline projects have been reviewed under these new laws to date.

Islander East Project

Project overview

The Islander East Project is a cooperative effort by two separate companies, Duke Energy Gas Transmission and KeySpan Energy. The proposed project would involve construction of approximately 44.8 miles of new 24-inch-diameter interstate natural gas pipeline that would begin from North Haven, Connecticut, cross Long Island Sound to a landfall in Shoreham, New York, and terminate in Brookhaven, New York. Roughly 10.2 miles of the pipeline would be located in Connecticut and 12 miles would be located in Long Island, New York. The remaining 22.6 miles of pipeline would be located in Long Island Sound, including 11 miles in Connecticut waters and 11.6 miles in New York waters. The purpose of the project is to provide natural gas to electric generation facilities and local gas distribution companies on Long Island and in New York City and to provide a second, separate natural gas transmission crossing to Long Island, New York. The project would also provide additional pipeline capacity and higher gas pressures to increase the availability of natural gas in the Connecticut market.

Project certification

Islander East filed its application for a Certificate with the FERC in June 2001. After completing a 14-month long environmental review of the project, which included staff site visits, public hearings, and the preparation of draft and final EIS's, the FERC issued a Certificate on September 19, 2002. In issuing its Certificate, the FERC approved Islander East's proposed construction methods and found the project to be both environmentally acceptable and critically needed to ensure the security and reliability of the natural gas delivery system to Long Island and the region. On January 18, 2003, FERC reaffirmed its Certificate in its Order on Rehearing and Issuing Certificates specifically addressed concerns raised by the Attorney General for Connecticut and the Connecticut Department of Environmental Protection (CTDEP).

Post-certificate issues

Following receipt of its Certificate, Islander East continued to coordinate with the CTDEP, New York State Department of Environmental Conservation, New York State Department of State, and the COE to obtain authorizations required by the CWA, Rivers and Harbors Act, and CZMA. Shortly after issuance of the Certificate, the New York State agencies completed their review and issued Islander East a Section 401 Water Quality Certificate and a general consistency concurrence confirming that the Project is consistent with the enforceable policies of New York's Coastal Zone Management Program.

Unlike New York, the CTDEP objected to Islander East's CZMA consistency certification. On April 12, 2002, Islander East submitted a request to the CTDEP for a federal CZMA consistency determination. By letter dated October 15, 2002, CTDEP advised Islander East that the Project was inconsistent with Connecticut's federally approved coastal zone management plan. CTDEP acknowledged that energy facilities like those proposed by Islander East are, by definition, facilities which are in the national interest. Nevertheless, CTDEP determined that Islander East would cause significant adverse environmental impacts on coastal resources. Specifically, CTDEP cited adverse impacts on water quality, shellfish habitat, water dependent uses and tidal wetlands. In addition, CTDEP expressed a preference for one alternative evaluated in Islander East's Final EIS, which was based on a project proposed by another pipeline company, but was no longer being pursued by the project sponsor.

On November 14, 2002, Islander East filed a Notice of Appeal with the U.S. Secretary of Commerce to obtain a federal override of Connecticut's denial of the CZMA consistency determination. On March 14, 2003, the parties (CTDEP and Islander East) requested that the Secretary stay the processing of the appeal to allow settlement negotiations to occur between Islander East and the CTDEP. On May 15, 2003, Islander East requested that the matter be remanded to Connecticut based on Islander East's submission of new information related to construction techniques that was the result of additional consultations with various state and federal agencies. Connecticut issued its Denial of the Remand in June 2003 and the matter was then sent back to the Secretary of Commerce.

The Secretary of Commerce reviewed the information provided by both parties and, in a decision on May 5, 2004, ruled that the project was consistent with the objectives of the CZMA and that federal agencies may issue permits and licenses for the project. In its Decision and Findings the Secretary wrote that "Islander East Project furthers the national interest in a significant and substantial manner; the national interest furthered by the Project outweighs the Project's adverse coastal effects; and that there is no reasonable alternative available for the project." The State of Connecticut has since filed a suit against the U.S. Department of Commerce to block the federal override. The final decision will be left to the court.

On February 5, 2004, the CTDEP denied Islander East authorization under Section 401 of the CWA. Unlike the CZMA process, there is no federal override provision for Water Quality Certification. Islander East requested that the CTDEP reconsider its decision by filing a Petition for Declaratory Ruling in April 2004. The CTDEP did not reverse its decision, so Islander East is pursuing other legal options.

As previously mentioned, the COE is unable to issue permits for the proposed project due to the denial by the State of Connecticut of the Section 401 permit. Islander East continues to work to resolve the permitting impasse.

Project milestones

Milestones associated with environmental permitting of the Islander East project are summarized below:

- June 15, 2001 - Islander East applies for a Certificate from the Federal Energy Regulatory Commission;
- February 13, 2002 - Islander East files a permit application with the CTDEP for a Section 401 Water Quality Certificate and CZMA consistency determination;
- March 22, 2002 - Islander East files permit applications for Section 10 and Section 404 approval with the COE;
- September 19, 2002 - FERC issues a Certificate based on the proposed route analyzed in the final EIS published in August 2002;
- October 15, 2002 - Islander East's application for CZMA consistency determination is denied;
- November 14, 2002, Islander East files a Notice of Appeal of Connecticut's denial of the consistency determination with the U.S. Secretary of Commerce, seeking a federal override of Connecticut's denial;
- January 14, 2003 - Islander East receives its New York CZMA consistency determination from the New York State Department of State;
- February 7, 2003 - Islander East receives its Section 401 Water Quality Certificate from the New York State Department of Environmental Conservation;
- July 29, 2003 - CTDEP denies Islander East's remanded CZMA consistency determination;
- February 5, 2004 - The CTDEP denies Islander East's Section 401 Water Quality Certificate application; and
- May 5, 2004 - U.S. Department of Commerce rules in Islander East's favor in Islander East's appeal to the Connecticut coastal zone consistency denial.

Recent developments

Islander East filed its COE Section 404 permit application on March 22, 2002. The COE is unable to review and permit the proposed action until Islander East resolves its permitting issues with the CTDEP for the 401 Water Quality Certification. Islander East continues to work to resolve the permitting impasse.

DISCUSSION

While the details of these projects are intriguing, there is a broader message that should be considered by project planners and regulators. The certification process is not necessarily sufficient to ensure project approval, especially for controversial projects where political pressure is applied to state agencies. Project opponents are aware that if the approval process can be delayed long enough, there is a chance that the market conditions will change and the project will be cancelled.

From one perspective, delays at the state or local level are inconsistent with the legal framework that has been established to govern natural gas pipelines, particularly interstate pipelines. For example, between 1911 and 1928, several states attempted to assert regulatory oversight of interstate natural gas pipelines. In a series of decisions, however, the U.S. Supreme Court held that such state oversight violated the interstate commerce clause of the U.S. Constitution. These cases, known as the "Supreme Court Commerce Clause" cases, essentially stated that interstate pipeline companies were beyond the regulatory power of state-level government. Alternatively, many would argue that a thorough review of pipeline projects at the state and local level is essential to add an element of local oversight necessary for a project to be reviewed with the unique environmental interests of the state or locality at the forefront.

In recognizing the importance of state and local environmental review for pipeline projects, the FERC has long since encouraged applicants seeking a Certificate to cooperate with state, local, and other federal agencies. Moreover, the FERC has recently begun encouraging applicants to begin using its NEPA Pre-filing Process whereby the FERC and the other agencies are engaged earlier in the project planning process. The intent of this process is to expedite the review and approval of pipeline projects by the following:

- working together and with applicants and other stakeholders, as appropriate, before complete applications for the necessary authorizations are filed;
- identifying and resolving issues as quickly as possible; and
- attempting to build consensus among governmental agencies and the various local stakeholders.

Largely developed in response to Executive Order 13212 that directed federal agencies to take appropriate actions to expedite their reviews of energy projects, the FERC's NEPA Pre-filing Process allows more input into the environmental analyses for pipeline projects. Presumably these analyses will be more thorough and allow more time to resolve any potential conflicts with other agencies.

While the FERC is taking steps to work more closely with other agencies to resolve issues, it is unlikely that these efforts will avoid future project delays if a state agency is determined to change a route or even block a project. As such, federal legislation is being pursued that would make it more difficult to unreasonably delay interstate pipeline projects. Although it was not passed, the proposed Energy Policy Act debated in the U.S. Congress during 2002 and 2003 included language that would further strengthen the FERC's role in regulating some interstate pipelines and that would provide a legal framework for pipeline companies to more rapidly resolve conflicts associated with the CZMA.

For intrastate pipelines and as discussed previously, Wisconsin recently created a special energy group within the WDNR to review and permit pipeline projects certificated by the PSCW. This model is yet to be tested in Wisconsin, and given funding constraints and the relatively few projects that apply for state certification, it is unclear whether the energy group will be able to maintain its role in the long term. In contrast, the New York Public Service Commission's (NYPSC) Article VII Certificate currently conveys all state permits to an applicant receiving approval to build an interstate pipeline. Other New York agencies are allowed to comment and suggest Certificate conditions, but do not issue their own permits.

CONCLUSIONS

Planning natural gas pipeline projects has always been complex, and applicants and agencies have had to sort out various levels of overlapping jurisdiction. The project certification process can break down in the case of controversial projects or where there is no effective mechanism for agencies to collaborate. Recent initiatives have attempted to address this situation, but in most cases there is not a sufficient track record to determine how successful these modifications will be. Without clear legislative intent, decisions on energy infrastructure will likely be increasingly difficult. As efforts continue to develop workable interagency processes, it appears that it will behoove project sponsors to conduct up-front research on agency mandates and potential conflicts, incorporate regulatory uncertainty into project planning and, to the extent possible, encourage and facilitate interagency cooperation early in the permitting process.

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REFERENCES

British Columbia Utilities Commission. 2004. Commission Order No. G-79-04 and Notice of Pre-Hearing Conference combining the reviews of the 2004 Resource Plan and the Certificate of Public Convenience and Necessity Application for a Liquefied Natural Gas (LNG) Storage Project. http://www.bcuc.com/ApplicationView.aspx?ApplicationId=58

Business Journal of Milwaukee. 2003. Guest Comment: Regulatory process needs to be improved. April.

Executive Order No. 13212. 2001. Actions to Expedite Energy-Related Projects. May.

Federal Energy Regulatory Commission. 2002. Final Environmental Impact Statement for the Georgia Strait Crossing Project, Georgia Strait Crossing Pipeline LP, Docket Nos. CP01-176-000 and CP01-179-000. July.

Federal Energy Regulatory Commission. 2002. Islander East Pipeline Project, Final Environmental Impact Statement, Docket No. CP01-384-0000 and Docket No. CP01-387-000. August.

Federal Energy Regulatory Commission. 2003. Islander East Pipeline Project, Order on Rehearing, Docket Nos. CP01-384-002, CP01-385-002, CP01-386-002, and CP01-387-002. January.

Interagency Agreement on Early Coordination for Interstate Natural Gas Pipelines. 2002. May.

Public Service Commission of Wisconsin. 2001. Final Decision and Certificate of Authority, Docket No. 6650-CG-194. July.

Public Service Commission of Wisconsin. 2003. Amended Final Decision, Docket No. 6650-CG-194. April.

Secretary of Commerce. 2004. Decision and Findings by the U.S. Secretary of Commerce in the Consistency Appeal of Islander East Pipeline Company, L.L.C. from an Objection by the State of Connecticut. May.

Washington Department of Ecology. 1998. State Environmental Policy Act Handbook. Washington Department of Ecology, Shorelands and Environmental Assistance Program. Publication #98-114. September. http://www.ecy.wa.gov/programs/sea/sepa/e-review.html

Washington Department of Ecology (WDOE). 2004. Georgia Strait Crossing Project – Final Supplemental Environmental Impact Statement. Prepared by Shapiro and Associates, Inc. for the Washington Department of Ecology. January.

Wisconsin Administrative Code Chapter NR 103, Water Quality Standards for Wetlands.

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Planning a Large Diameter Pipeline in a Multi-Use Urban Corridor

Mario E. Buszynski

The lack of foresight by municipalities and others in preserving corridors for utilities means that there are increasingly fewer opportunities to locate linear facilities in large urban centers such as the City of Toronto. In those corridors that do exist, there are competing land uses that make it difficult to accommodate any new use. Adjacent land uses may also compound the problem further. In 2003, the Ontario Energy Board approved new *Environmental Guidelines for the Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario.* The guidelines include specific new requirements for planning pipelines in urban areas. These requirements involve the identification of indirectly affected landowners and a more detailed analysis of land uses and their values in an urban setting. Through the use of a case study, this paper describes the special urban issues that were encountered in planning the location of a 914 mm (36 inch) diameter natural gas pipeline through residential and industrial neighborhoods. It also describes how the new guidelines were incorporated into the planning process. It begins with a rationale for the study area selected. A description of the special urban issues follows. The techniques used to address these issues and the success of the public involvement program that identified 3,200 indirectly affected landowners is documented. The study results illustrate that it is possible to plan a right-of-way through an urban corridor in such a manner as to be compatible with existing development, conform to Energy Board guidelines and minimize the amount of remedial work to mitigate the impacts occurring on and adjacent to the right-of-way.

Keywords: Ontario Energy Board Guidelines, pipeline planning, urban issues, right-of-way

INTRODUCTION

In 2003, a new 550-megawatt gas-fired generating station was proposed for the Portlands area in downtown Toronto. In order to ensure that there was a sufficient supply of natural gas, the project proponents (Ontario Power Generation and TransCanada Energy) contacted Enbridge Gas Distribution (Enbridge). Enbridge undertook a study of their existing system. This study determined that although the proposed generating station site was presently supplied with natural gas, there would have to be modifications made to the existing gas distribution system in the area in order to reliably supply the facility with natural gas. These modifications included the addition of a seven-kilometer section of 914 mm (36 inch) diameter pipeline (NPS 36).

The study area chosen for the new pipeline is illustrated in Figure 1. It was determined that the part of the distribution system that required reinforcement in order to supply the Portlands generating station was located in the eastern part of the Greater Toronto Area. Specifically, the study area was centered on an existing Enbridge 762 mm (30 inch) diameter pipeline (NPS 30) running either within an electric transmission corridor or on an Enbridge-owned right-of-way. This pipeline is located in a north-south direction east of the Don Valley Expressway/Highway 404 corridor.

A corridor selection study identified a number of north-south options identified, as in Figure 1. The combination of existing electric transmission line corridors and Enbridge owned rights-of-way provided the

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Fig. 1. Pipeline options.

best environmental and technical option for the new pipeline. The area chosen for the route selection study was approximately 14 kilometres long. Since a seven kilometer pipeline was required, it naturally broke into two study areas, Study Area A, which was bounded on the south by Eglinton Avenue East and on the north by

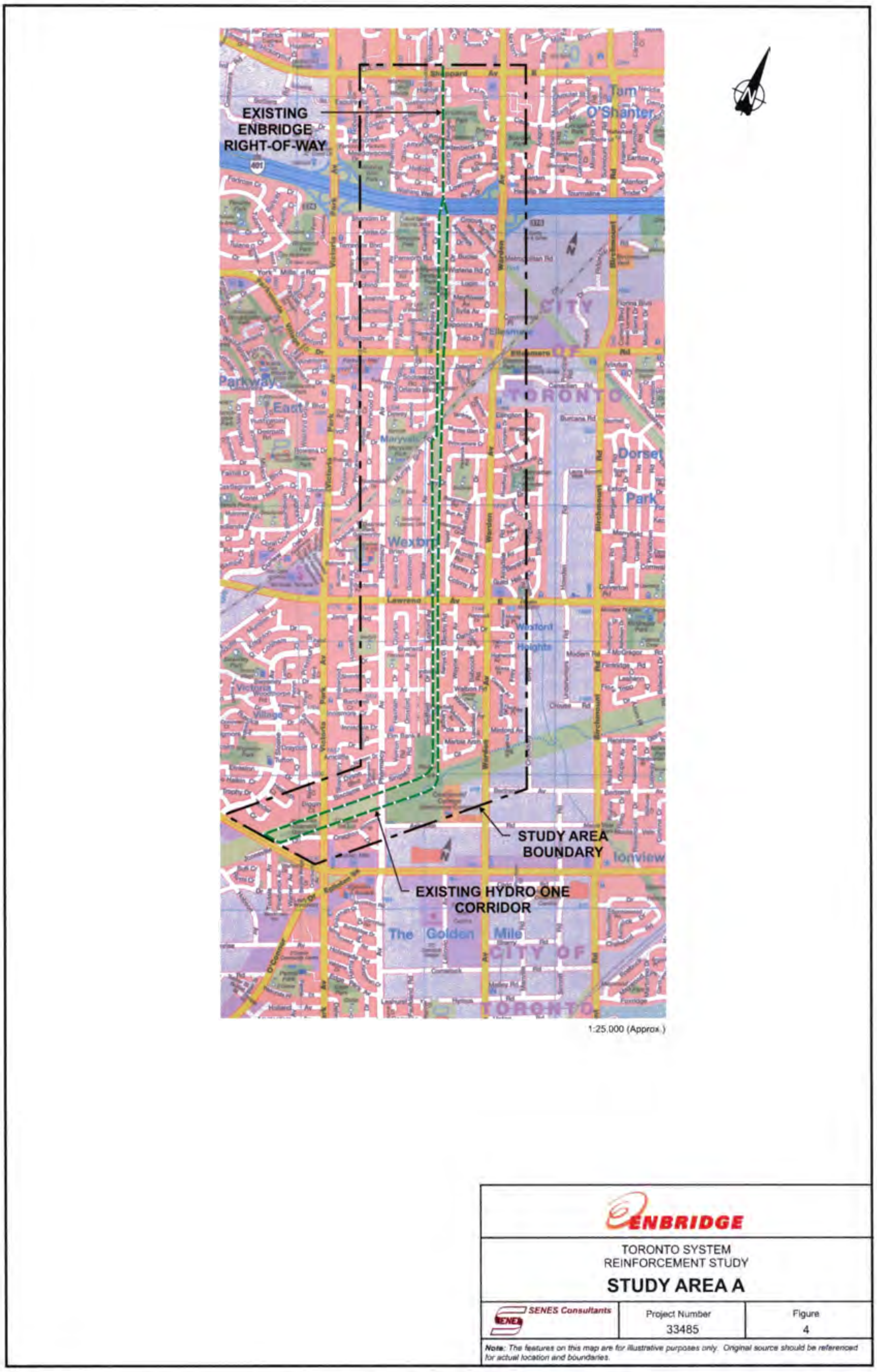

Fig. 2. Study area A.

Sheppard Avenue East in the City of Toronto. Study Area B used Sheppard Avenue East as the southern boundary and extended north to 14th Avenue in the City of Markham. The study area was selected from a number of linear alternatives as having the least number of significant environmental constraints. The

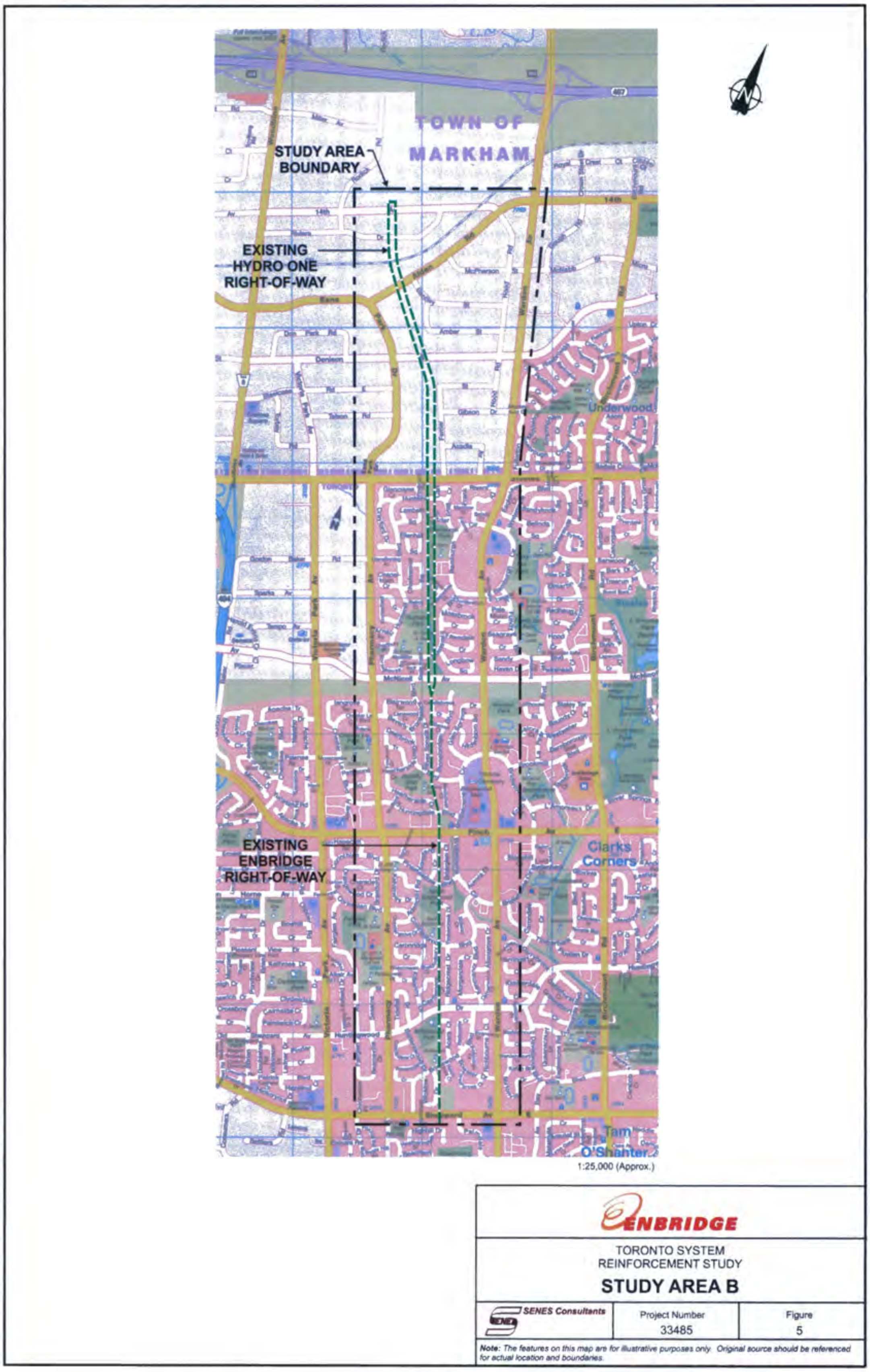

Fig. 3. Study area B.

ability to parallel an existing, large diameter natural gas pipeline was also seen as an advantage since adjacent residents are used to this type of facility in proximity to them.

APPROVAL PROCESS

In order to secure approval for a new, natural gas distribution pipeline in Ontario, a "Leave to Construct" application must be filed with the Ontario Energy Board (OEB). A route selection and environmental assessment of the preferred pipeline route forms part of the application. In order to secure approval of the environmental assessment by the OEB, pipeline companies must follow a set process. This process is described in the OEB's "Environmental Guidelines For The Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario" (the Guidelines). The fifth edition of this document, published in May, 2003, identifies a number of new guidelines related to planning facilities in urban areas. Some of these guidelines that have relevance for this project include the following:

- Direct notification should also be provided to any indirectly affected landowners whose property has been identified as being within a zone of impact resulting from pipeline construction or operation;
- The identification of indirectly affected landowners is particularly important in urban settings where population densities may be high and a large number of persons could potentially be affected by a facilities project;
- Consideration must be given to the impacts of pipeline construction and operation on the different land uses found in the urban environment;
- All reasonable efforts should be made to locate proposed pipeline facilities adjacent to or on existing utility or transportation corridors;
- In urban settings, issues such as traffic safety, commercial business disruption, proximity to institutions such as schools and hospitals and the impacts on local residents may require increased attention during the routing and site selection stage;
- Contaminated sites should be avoided where practical; and
- Protection of trees and other vegetation is of special importance.

All of the information contained within the OEB's Guidelines is to be complied with when planning new facilities, as well as during and after completion of construction. Once the OEB is satisfied that a proposed project is in the public interest (i.e. need, economic feasibility and minimizing adverse environmental effects) it will then authorize construction of the new facilities.

The Ontario Pipeline Coordinating Committee (OPCC) is comprised of provincial agencies that may have concerns related to pipeline projects. The purpose of the OPCC is to coordinate the provincial government review. In additional to provincial members, the affected municipalities and conservation authorities also participate in the OPCC review. The Chair of the OPCC (who is also a Board staff member) coordinates the review of the environmental assessment and forwards the results of the review to the applicant and the OEB.

IDENTIFICATION AND RESOLUTION OF ISSUES

Through discussions with municipal and provincial agencies, a preliminary list of issues was developed. Since the alternatives involved urban and industrial development in proximity to existing electric transmission rights-of-way and Enbridge owned lands, the initial list of issues was relatively straightforward.

Issues included the usual ones associated with construction (e.g. noise, vibration, dust and traffic). Secondary use of the electric transmission rights-of-way (parking lots, transformer station, allotment gardens, bicycle paths and other utilities) resulted in the identification of a number of additional issues. The rights-of-way have been landscaped with shrubs and trees in some locations and have recreational facilities like asphalt bicycle paths and walking trails located on them. The removal of ornamental vegetation was also considered to be an issue since a significant amount of investment was made. In the case of tree removal, it could change the aesthetics of the right-of-way and in some cases result in loss of privacy and/or shade to adjacent residential properties.

Notification of directly and indirectly affected residents

Under the new OEB Guidelines, in addition to notifying directly affected property owners, a zone of impact has to be defined and anyone located within the zone is to be directly notified. The first step is to define the zone. In order to do this, pipeline impacts during construction such as noise, vibration, dust and traffic were reviewed and the possible extent of their impact assessed. This resulted in a notification area that in some cases extended several streets away from the actual right-of-way. The notification problem was compounded by the recent introduction of new privacy legislation. In the past, municipalities were able to provide computer generated property owner mailing lists with very little effort. This service is no longer available, resulting in a more costly process where street numbers are determined from city maps or by driving the area and impersonal letters to "the property owner" are mailed.

It is even more difficult to notify directly affected residents. Where private property is directly affected, a title search may be required. In the case of the Portlands Reinforcement Pipeline, electric transmission rights-of-way were chosen as alternatives. Secondary uses on the rights-of-way such as the City of Toronto's rented garden plots were not able to be captured through property searches. The City was unwilling to provide property owner lists. After much discussion, a compromise was reached in which SENES would draft the letter and the City would mail it to the affected individuals.

Tree clearing

Trees located in urban areas take on a greater significance to individual property owners. In addition to improving aesthetics, trees may provide shade, visual screening and shelter from the elements. Trees in urban areas generally compete for space with other land uses and are generally a dwindling resource. Municipalities such as the City of Toronto have strict by-laws covering the removal of trees.

Trees were located primarily on the edges of the electric transmission rights-of way, since they could interfere with the transmission lines. On the portion of the alternatives that occupied the Enbridge owned right-of-way, trees were located over much of the area. Many of the trees were planted by property owners adjacent to the rights-of-way. While Enbridge is legally entitled to remove them, the trees provide a visual screen and shade to their properties. They also provide slope stabilization in some areas. Selective cutting was determined to be the best method of tree removal. In some cases, smaller trees will be able to be salvaged through the use of a tree spade (a large machine that can mechanically extract the tree and root ball from the ground and replant it in a different location). Due to the narrowness of the Enbridge owned right-of-way, it may not be possible to replant all of the trees on the right-of-way. In this case, possible plantings in a different location may be considered.


公眾通知
建議擴展天然氣傳送系統公眾會議

Enbridge Gas Distribution 計劃向安省能源局申請興建一條直徑 36 吋(914 mm)，約 6.5 km 長的天然氣傳送管道。管道將會與現行多倫多區的 30 吋(762 mm)直徑天然氣傳送管平衡。建議的管道將配合多倫多區對天然氣日益增加的需求。如安省能源局批准，預計工程將於 2005 年春或秋完成。

茲顧及此工程對環境及社會經濟的影響，SENES 顧問公司已於 6 月 23 日舉行了一個公眾諮詢會議。SENES 公司現已將當天公眾對兩條建議路線的意見結合政府的建議，策劃了一條新的喉管路線(路線 A)。此線路由 EGLINTON AVE.東至 WEXFORD PARK 北行 401 公路直至 SHEPPARD 大道。由 401 至 SHEPPARD 大道是屬於 ENBRIDGE 的優先權範圍。

我們歡迎閣下參加 2003 年 10 月 6 日星期一舉行的公眾會議，時間分別是下午 4:00pm 至 6:00pm 及 7:00pm 至 9:00pm，地點是 20 Canadian Rd.，Costco Outlet 側的 Ellesmere Community Centre。屆時 Enbridge Gas Distribution 及 SENES 均會派出代表與公眾討論建築工程對閣下居住地區的影響。閣下的寶貴意見會在最後決定時認真參考！

欲知詳情，請瀏覽工程網址
www.enbridge.com/torontoportlands
或致電以下人士查詢

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Fig. 4. Notification.

Parks and recreation

Linear systems such as electric transmission rights-of-way become green corridors within a city. There were walking paths, bicycle paths, soccer and cricket fields and parking areas located on the rights-of-way. Some of the parks located adjacent to the right-of-way have children's playgrounds associated with them. There was a desire expressed by the City to ensure public safety during construction. In certain areas, ornamental plantings of vegetation beautified the area. This posed a problem for construction and generated a

Fig. 5. Tree clearing.

Fig. 6. Parks and recreation.

great deal of public interest. The key issue appeared to be conflict with scheduled recreational use of the recreational fields, since this type of public space is relatively rare in the area. The problem can be solved through scheduling those areas for construction in the off-season (after September 1). Restoration of the landscaped areas is more difficult since it took many years for the landscaping to mature. New plantings will be done in co-operation with an arborist from the City of Toronto.

Schools

The issue of pipeline safety and schools was raised during the study. The question of pipeline safety during operation was addressed by the following points:

- The existing pipeline to be looped has been operating without incident for more than 30 years;
- A recent safety inspection of the existing pipeline found it to be in excellent working order;
- The alternative routes are all on secured utility rights-of-way so that third party damage is not an issue; and
- The proposed pipeline would be located in proximity to the existing pipeline in a well-marked right-of-way.

Safety during construction was another issue. In order to ensure the safety of school children, construction in proximity to schools was scheduled for the summer holiday period when most children would be away from school. The construction area will be fenced and it was proposed that security personnel be hired to watch the construction area at night. The usual precautions of not leaving large areas of open trench and minimizing off right-of-way traffic were also recommended.

Pedestrian access

Many people cross the rights-of-way in order to get to the community and or facilities on the opposite side. In many cases these pedestrian crossings are extensions of public road allowances. In some cases, people use these areas in order to access the rights-of way in order to walk their dogs, hike or recreate. Footpaths tend to be hard surfaced, either asphalt or concrete and in areas of steeper slopes, have stairways associated with them. Maintaining pedestrian access during construction was identified as a significant concern at the public open house meetings. Where possible, construction will not hinder pedestrian access and if it is necessary to close access, it will only be for a short duration.

Side slope issues

Side slopes represent a serious issue in the narrower parts of the rights-of-way being considered. Since the west sides of the rights-of-way being considered (located on the Enbridge-owned lands) are significantly lower than those lands on the east sides, erosion, flooding, sedimentation and bank instability could result. This could be compounded by removal of vegetation on the slope in order to install the pipeline. The solution devised involved leveling the top of the slope in order to provide a route for the excavators and dump trucks. The spoil was to be trucked off the right-of-way to temporary storage areas and vegetation was to be selectively removed and reestablished as soon as possible to minimize erosion. The use of erosion control matting was also called for. The narrowness of the right-of-way in these locations, coupled with the steep slopes, presents one of the most significant challenges to the project.

Fig. 7. Pedestrian access.

Fig. 8. Side slope issues.

Allotment gardens

Finding an intensive agricultural operation being undertaken in the heart of a large urban city is surprising. Allotment gardens were developed by the City of Toronto on a number of electric transmission rights-of-way in order to provide apartment dwellers with an opportunity to cultivate a small piece of land near their residences. The allotment gardens consist of a large number of plots of up to 30 square metres each. These plots were found to grow a large variety of vegetables, ornamental plants and flowers. The soil productivity has been significantly increased through the use of fertilizers. Vegetables included tomatoes, cucumbers, peppers and eggplant. This type of crop requires plant-

Fig. 9. Allotment gardens.

ing each year. Thus, by waiting until the fall in this area, it would allow the allotment gardeners to harvest their crops. Other standard agricultural practices such as separation of the topsoil from the subsoil, minimizing the width of the right-of-way, wet soil shutdown protocol and using lightweight vehicles in the area will help to return the land to its former productivity. Monitoring crop productivity in the next two growing seasons will also help to ensure that the allotment gardens are returned to their former productivity.

Other urban encumbrances

An existing right-of-way in an urban area is a magnet for utility uses such as low voltage electrical distribution lines, transformer stations, telephone lines, water mains and sewer lines. In addition, the vacant surface space is desired for overflow parking lots, landscaping and storage. Fortunately, none of these uses are critical to the operation of the adjacent business and thus can be temporarily disturbed by pipeline construction. Appropriate mitigation measures for sub-surface and surface structures are required in order that pipeline impacts are only of a temporary nature.

SUMMARY AND CONCLUSIONS

Construction impacts are felt over a greater area than in cross-country pipeline construction due to the built up nature of the urban areas. This results in a great number of indirectly affected people. It is a challenge to identify indirectly affected people for the purpose of notification. Public communication is essential and a website is a necessity on a large project in order to ensure that people have access to project information.

The type of construction impacts include all of the "usual suspects." In addition, the urban infrastructure poses other challenges of multiple utility crossings and other intensive and sometimes competing land uses. Mitigation measures have to be well thought out and it is very important that they are followed during construction. Follow-up monitoring is also very important.

The types of mitigation proposed to resolve urban issues are appropriate for other projects in urban areas. Urban projects of this nature will become more prevalent in the future as the demand for natural gas grows.

BIOGRAPHICAL SKETCH

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Permitting and Building an Oil Pipeline in Lago Agrio, Ecuador

Fernando L. Benalcazar and Mark Thurber

The Ecuadorian Amazon has a history of conflict over large petroleum infrastructure projects, particularly pipelines. The rapidly growing city of Lago Agrio is at one terminus of the recently constructed and controversial OCP Trans-Andean export pipeline and is the location of a legal dispute over impacts from petroleum development in the 1970s. EnCana was faced with the difficult task in 2002 of permitting and building a crude oil pipeline around this city to connect with OCP. EnCana analyzed thirteen different ROW alternatives, jointly with other petroleum companies interested in sharing the ROW to determine the three best alternatives. The goals were to minimize social and environmental impacts, allow for sharing of a ROW with four different oil companies, be compatible with the Lago Agrio plans for urban growth, and be economically and technical feasible. These three alternatives were presented to the external stakeholders including: local, regional and national governments, community councils, individual land owners, religious organizations and NGOs. A key strategic decision was made by EnCana to maintain transparency throughout the consultation process and flexibility in the final design, despite the atmosphere of conflict. The product of this process was a fourth alternative that addressed specific micro-routing issues, public participation in monitoring, and a special exemption from the hydrocarbon law to allow multiple pipelines in a single ROW. The pipelines in the ROW were constructed in 2002–2003 with no public controversy and have been operating to date without incidents.

Keywords: Pipeline, negotiation, stakeholder, right-of-way

PROJECT AND MISSION

The project objective was to build EnCana's Lago Agrio Tank Farm (designed storage capacity of 200,000 barrels −100,000 currently installed) and a 10 kilometer oil pipeline connecting to the Amazonas Station of the Heavy Crude Oil Pipeline – OCP (Oleoducto de Crudos Pesados in Spanish) in the city of Lago Agrio, Sucumbios Province of Ecuador. Managing the right-of-way (ROW) of this pipeline required an innovative approach to minimize the social impacts, considering that three other petroleum producers were also planning to install pipelines across Lago Agrio. The current hydrocarbon regulation requires a 25-meter-wide ROW per pipeline. Despite this hurdle, EnCana initiated discussion with the other producers to share a single ROW among four companies in order to reduce spatial impacts. This project of sharing a single ROW is the first in Ecuador.

EnCana's pipeline is a 16″ diameter buried pipeline, which loops to the south of the city in a low-growth-rate rural area. It is 9.20 kilometers long with a remote oil spill detection system. The estimated construction time was four months. Non-skilled job opportunities as well as some skilled positions were provided to local community members in order to help address the high unemployment in the region, which is currently 14.40% (INEC, 2001).

The mission of this project was to build the storage facility and associated pipeline within budget and schedule, while openly engaging all stakeholders. EnCana has a strong corporate commitment to creating a transparent negotiating environment for the public consultation process, and to maintain flexibility in the final design. This approach is a distinct change in philosophy from historical projects in Lago Agrio, which have often been developed in an atmosphere of conflict due to a lack of trust with stakeholders.

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STAKEHOLDER ENGAGEMENT

Lago Agrio grew out the oil-boom of the 1970s, expanding from a remote production field located in primary rainforest. Urban development and population growth of this boomtown has been chaotic and disorganized. New neighborhoods have been developed on top of existing ROWs, key city properties are located next to tank farms, etc. Lago Agrio is also the center of a legal dispute over impacts from the petroleum industry and its development in the 1970s. Local communities including immigrant farmers and indigenous tribes are still calling for international attention to these residual social and environmental impacts. The relationships between some stakeholders and the OCP project were tense, which made consensus building difficult. Another critical factor was the political affiliation of the city mayor. The Mayor's party has generally been in opposition to foreign multinational company activities, especially those related to the petroleum business. This backdrop of controversy required that EnCana be creative and manage an aggressive stakeholder engagement plan in order to succeed. A specific Engagement Strategy was drafted for all of EnCana's internal stakeholders before project implementation.

ENGAGEMENT STRATEGY

Key stakeholders were identified including: local authorities, provincial and central government entities, civic organizations, local church organizations and other interested informally organized parties. The objective of this strategy was to define parameters and boundaries to engage all stakeholders, including regulatory bodies, with fair compensation and sustainability factors, as well as, adequate environmental and social management of the project.

Specific objectives

Four specific objectives were established, as follows:

1. Identify and apply the highest environmental standards for the pipeline construction and operation phase, searching for the best pipeline route, less intrusive, with community consensus and support;
2. Establish the synergies and connections with the civil society and other stakeholders including community leaders, environmental groups, local authorities and the church;
3. Negotiate a large compensation project, which is socially oriented and with real community backing including consent of the civil society and local government local authority, e.g. local mayor, city council, etc.; and
4. Execute the project with no social, environmental or safety incidents.

Methodology

In order to achieve the specific objectives, as part of the engagement strategy, the following steps were taken:

1. A multidisciplinary team was established to initiate dialog with the community, build consensus and negotiate compensation;
2. Review and systematization of information provided by secondary sources;
3. Engagement with key stakeholders and representatives of regulatory bodies; and
4. Discuss and analyze primary and secondary environmental and social impacts of the pipeline project development and reach consensus with stakeholders for its execution.

Multidisciplinary team

The multidisciplinary team included personnel with adequate skills and experience in civil engineering, environmental engineering, social management, conflict resolution and negotiation, media management and communications. The team members were: (a) A manager for environmental, health, safety and community affairs (EHS-CA); two environmental/social advisors; a community relations advisor, for negotiation with civic and community organizations. (b) Two pipeline engineers for stakeholder awareness and technical project description and execution. (c) A 4-person team of community relations coordinators, for on site negotiations. (d) A social communication expert to manage local media at national level. (e) A social communications expert to manage the Lago Agrio and Amazon region media. (f) A consultant to provide the environmental and social impact assessment. Four tiers of interaction were pre-established in order to expedite interaction and timing, as follows:

1. Regulatory bodies of the central government;
2. Local and provincial authorities;
3. Civic and local organizations; and
4. Individual landowners and land acquisition.

Team working methodology

Transparency in project evaluation, stakeholder dialogue and compensation negotiation were the keys for success. The first approach was taken with the regulatory bodies of the central government, which provided feedback stemming from concerns of stakeholders in Lago Agrio regarding oil industry activities. A local and influential social communications expert was included on the team to manage the Lago Agrio and Amazon region media, and act as a liaison between the team and the civil society in search for project consensus. It was also decided to use an inductive negotiation method. First reach consensus with the bases of civil society (those most directly affected) and then move up to the local Mayor, as the elected representative of Lago Agrio city. This is a well-known principle: "many negotiation processes must be defined by the bases and not by the central power bodies" (Del Castillo, 2000).

The environmental and social impact assessment addressed the primary design goal of determining the least intrusive pipeline route considering current Lago Agrio demographics and infrastructure, environmental sensitivities and urban growth plans. The WALSH consulting firm identified thirteen possible alternatives, which were scrutinized using high resolution imagery (IKONOS, 2003) and aerial photography, prior to select the top seven based on additional considerations involving city expansion trends, river bank stability, existing oil infrastructure and pipelines ROW, hydrological conditions, soil stability, among others. The best three alternatives were determined using historical information based on 30 years of satellite imagery (LANDSAT, 1989) and other analyses performed by civil society representatives, Lago Agrio Municipal technical staff, representatives of the regulatory bodies of the central government, some non-organized groups, and the local church representative. The preferred route alternative was selected from these three alternatives, with the full participation of these stakeholders after the ground inspection and aerial inspection by helicopter. Some localized concerns were to be addressed by the team with micro-routing alternatives.

The alternative selection process also involved four pipelines within a single ROW with different owners and "tie-in points" along the ROW. EnCana obtained a power-of-attorney from the other producers to manage the environmental and social issues on their behalf. The route selection was also linked to the existence of a recently negotiated pipeline ROW, which connected to the OCP Amazonas Station. This section needed to be designed for five pipelines of five separate producers.

Communication and education

Managing and screening adequate information internally and externally, was a real challenge in order to communicate harmoniously with the stakeholders, the other three oil producers and other internal stakeholders. All field data, design and technical information, government approval status and stakeholder interaction reports were prepared accordingly with the target audience to reach permanent and effective communication. The community relations staff was paramount in providing feedback from the field. This enabled an effective communication and proper education of the different steps taken towards full Lago Agrio community acceptance and understanding.

Negotiation: Consensus and agreement

Once communication and education of the project were in place, a negotiation strategy with those community members directly affected by the project execution was initiated directly under the community relations staff. The EHS-CA Manager, with authority delegated by the other producers also initiated compensation negotiations with the city Mayor. Several presentations related to the project made known to community members and stakeholders' feedback were given to the Mayor and his staff. Two critical stakeholders participated in all meetings with the Municipal staff: a church representative and the local influential social communications expert. These individuals were witnesses of the transparency in the negotiation process and facilitated communication with the community as a whole.

The community relations advisor also interacted with the civil society stakeholders, among others: community organizations, trade organizations, unions, women associations, etc. in order to maintain open communication channels between the Mayor and his staff and EnCana's representative, which were critical for reaching agreement.

Dialog among all community stakeholders continued for several weeks until reaching a social compensation agreement, which was the construction of a public market building following the Municipality of Lago Agrio design requirements. This contribution was "in-kind" and to be built by EnCana fully in compliance with environmental and safety construction requirements. The public market selection was the result of a consensus of several alternatives discussed by the local stakeholders, in order to fulfill a Lago Agrio city need, which had been pending for several years. Additionally, EnCana committed to perform the pipeline construction activities under permanent community monitoring; to implement a health campaign during the construction phase; to provide all non-skilled job opportunities and some for skilled jobs to local community members; and to optimize utilization of local services, such as transportation, catering and monitoring; to implement an open community audit process during project execution and post-execution.

Project execution and completion

The project was initiated immediately after signing the compensation agreement and individual land owners' permits were granted for the ROW access and construction. A total of 400,000 worked man-hours accident free were reached and no social or environmental incident occurred during the whole process. Community monitors acted, as previously agreed, with full empowerment to verify EnCana's commitment to the Environmental and Social Management Plan. Four Community Audits were successfully executed and immediate corrective actions were implemented when necessary.

REFERENCES

INEC (Ecuador's National Statistics and Census Institute). Population Census 2001. Ecuador.

Del Castillo, Luis. 2000. Conflict Management: Building Consensus. Madrid, Spain.

IKONOS Color Satellite Image, 1 meter resolution, Bando Combination RGB 1,2,3. October 26, 2003.
LANDSAT 5 and LANDSAT 7 Satellite Image, 30 meter resolution; Thematic Mapper Sensor, Bands 5,4,3. August 7, 1989, August 9, 2001, October 14, 2002.

BIOGRAPHICAL SKETCHES

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Mr. Thurber is a geologist with ten years of experience as an environmental consultant for the petroleum industry in Ecuador. He currently manages the WALSH-Ecuador office, which provides environmental, community and archeological services. Mr. Thurber graduated from Wesleyan University in Earth Sciences and holds a M.S. in geology from the University of Washington. He participated in the UN World Summit on Sustainable Development (WSSD) as part of Ecuador's Official Delegation in Johannesburg, South Africa in 2002. Mr. Thurber and the WALSH-Ecuador team were recently honored with the Institute of Petroleum Award for the best Environmental Project for 2003.

Management of Electrical Risks in Transmission Line – Pipeline Shared Rights-of-Way

Jose R. Daconti

Difficulties establishing new rights-of-way for power lines and pipelines increase the need to locate these installations in shared corridors. This paper does not present the details of an engineering analysis, but rather introduces concepts regarding the potentially harmful effects to people and the pipeline due to proximity to a power line. Pipeline-induced disturbances, the coupling mechanisms (capacitive, inductive and conductive) between the two installations, and conditions under which the pipeline-induced disturbances should be evaluated are identified and discussed. Commonly-adopted safety limits are identified, mitigation methods to reduce unacceptable disturbances are discussed, and recommendations for pipeline design, construction and maintenance in shared rights-of-way are presented.

Keywords: Right-of-way, power line, pipeline, electromagnetic compatibility

PIPELINE INDUCED DISTURBANCES

Metallic pipelines used for fluid transportation (gas, oil, water) are usually underground, but they may also have sections above-ground. Underground sections are protected by an external anti-corrosive coating. Above-ground sections are usually uncoated (often just painted) and isolated from the underground sections by means of insulating joints. Both behave like long conductors insulated from the ground.

Overhead power lines as well as underground power lines can induce harmful disturbances on nearby metallic pipelines. Basically pipeline-induced disturbances are induced voltages on the pipeline metal. They are caused by the power line operating voltage and circulating currents. Some voltages are induced when the power line is under normal steady-state operating conditions while other induced voltages may occur only during short-circuits on the transmission line.

COUPLING MECHANISMS

Generally, a physical process of transferring disturbances to a nearby installation requires the existence of a disturbance source, a coupling mechanism, and a receptor. In the present analysis, the source of disturbances is the power line, the receptor is the metallic pipeline and the coupling mechanism is the capacitive, inductive and conductive coupling between power line and pipeline.

The capacitive coupling disturbance is produced by the electric field of the power line and needs to be evaluated only for above-ground sections of pipeline that are electrically isolated from the ground. As shown in Figure 1, the capacitive coupling functions as a capacitive voltage divider. Otherwise, there is no capacitance between the power line and underground sections of pipeline. Any pipeline-to-ground connection makes this disturbance negligible. Usually, the evaluation of this disturbance is performed only for steady-state operating conditions of the power line, assuming the line operates at its maximum operational voltage.

Figure 2 depicts that the inductive coupling disturbance is produced by the magnetic field of the power line and needs to be evaluated for underground sections of pipeline. Above-ground sections of pipeline require evaluation only if these sections are grounded. This disturbance depends directly on the transmission line current imbalance. Evaluation of this disturbance is usually performed for steady-state, as well as short-circuit operational conditions of the power line. This disturbance is evaluated taking into account the maximum anticipated levels of steady-state and short-circuit currents.

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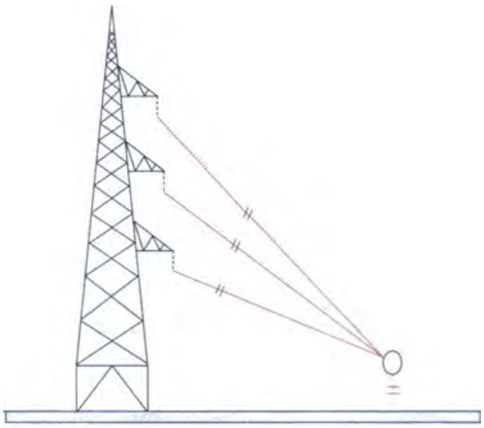

Fig. 1. Capacitive coupling.

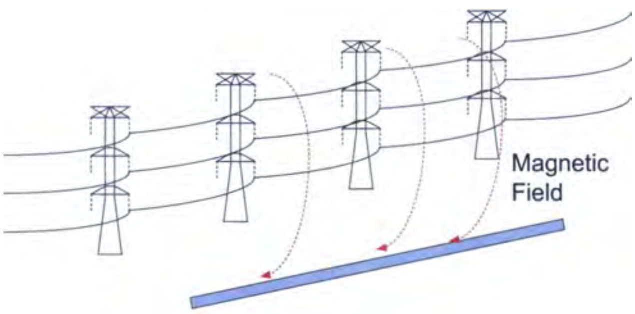

Fig. 2. Inductive coupling.

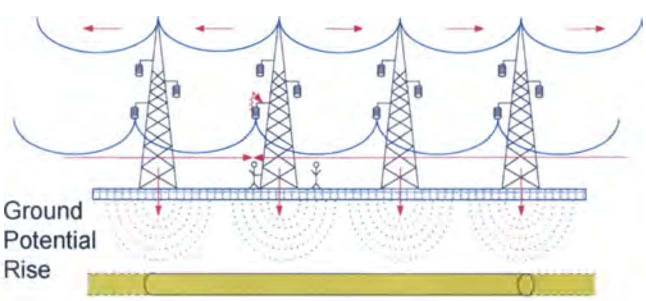

Fig. 3. Inductive and conductive coupling.

The conductive coupling disturbance is produced by the ground potential rise due to the electrical currents injected into the ground from the transmission line. It needs to be evaluated for underground sections of pipeline and for those above-ground sections that are grounded. Evaluation of this disturbance is performed only for short-circuit conditions. This disturbance is evaluated taking into account the maximum anticipated level of short-circuit current. It is important to note that under short-circuit conditions, disturbances due to inductive and conductive coupling occur simultaneously as shown in Figure 3.

POTENTIAL RISKS

The most basic concern regarding proximity of a power line to a pipeline is that the electrical clearances

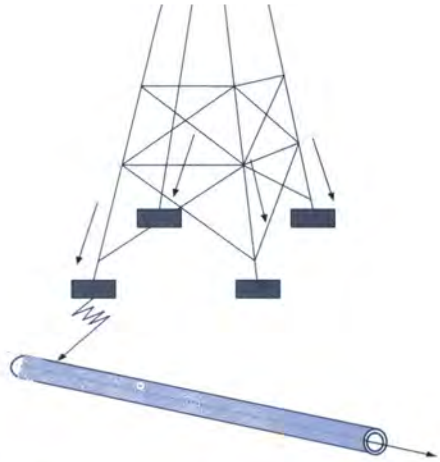

Fig. 4. Electrical discharge from power line to pipeline.

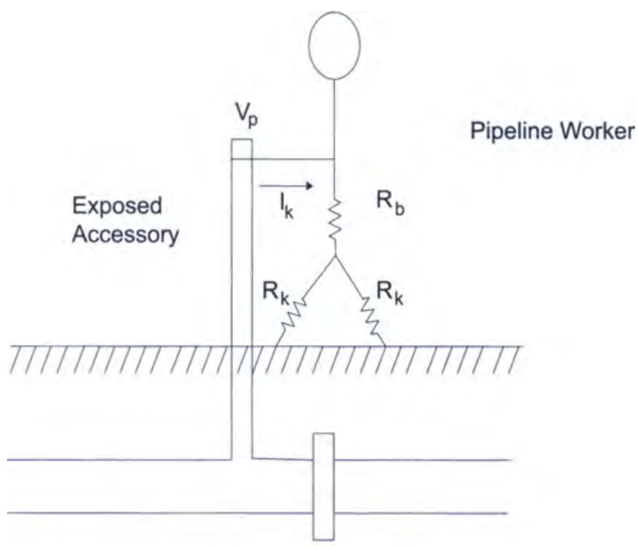

Fig. 5. Electric shock.

between the mentioned installations are large enough to avoid electrical discharges from the power line to the pipeline, as shown in Figure 4.

Further, the following risks may exist:

- Electric shocks to people who contact the pipeline can occur at above-ground sections of pipeline and above-ground metallic accessories connected to underground sections, as shown in Figure 5. Tolerance to electric shocks depends on shock duration;
- Damage to the pipeline insulating coating can happen at underground sections of pipeline as a consequence of the application of excessive voltage stress across the pipeline coating. The coating becomes internally exposed to the pipeline metal electric potential, Vp (produced by inductive plus conductive couplings), while becoming externally exposed to the local ground electric potential, Vs (produced by conductive coupling), as shown in Figure 6;
- Damage to the pipeline insulating joints can occur when insulating joints are used to separate above-ground from underground sections of pipeline or to

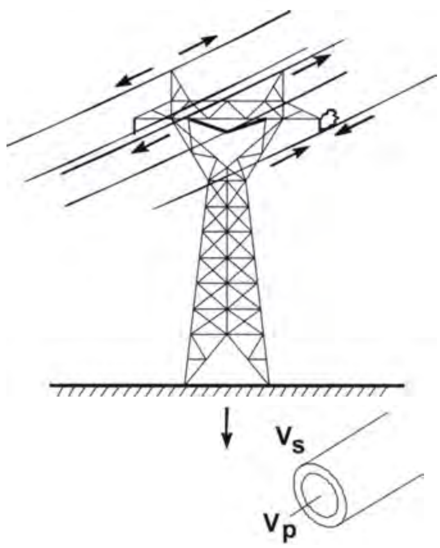

Fig. 6. Electrical stress applied to pipeline coating.

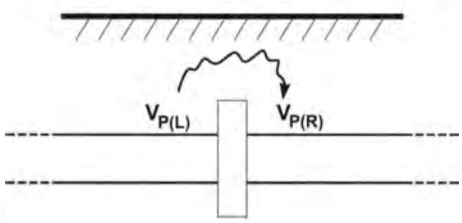

Fig. 7. Electrical stress applied to insulating joint.

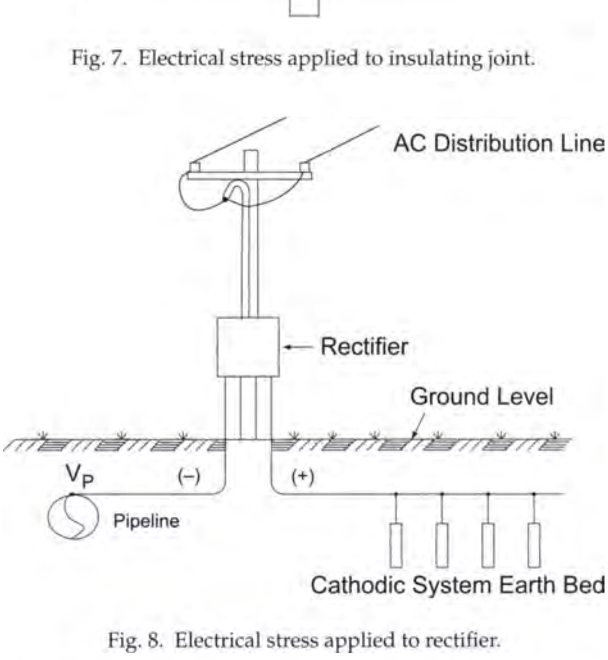

Fig. 8. Electrical stress applied to rectifier.

insulating joints used to separate pipeline sections connected to different cathodic protection systems. These insulating joints can be damaged if exposed to voltage stresses above their maximum capacity to withstand voltage, as shown in Figure 7;

- Damage to the pipeline cathodic protection systems can occur if the pipeline electric potential (at the point of connection to the cathodic protection system) is above the maximum reverse voltage tolerance of the cathodic protection system rectifier, as seen in Figure 8.

SAFETY CRITERIA

People who contact the pipeline can be exposed to electric shocks (touch voltages) caused by long-duration pipeline induced voltages (produced during the steady-state operation of the power line) or short-duration pipeline induced voltages (produced during short-circuit episodes on the power line). Typically, long-duration shocks should be limited to 5 mA (estimated shock current that would produce loss of muscular control for 0.5% of children), while short duration shocks should be limited to 164 mA (estimated minimum shock current that would produce a ventricular fibrillation probability equal to or less than 0.5% for a 50 kg weight person, according to Dalziel's Equation for a shock duration time equal to 0.5 seconds). Although these are typical limits, each country or state has its own regulation, which must be respected. For instance, New York State Pipeline Code requires that long-duration voltages induced on pipelines by electric lines must be limited to 15 volts.

Damage to the pipeline insulating (anti-corrosive) coating could lead to pipeline corrosion problems. This risk can be avoided if short-duration voltages applied across the pipeline external coating are limited to 5 kVrms. Such a level has been considered appropriate for the regularly used thicknesses of plastic (polyethylene) and bituminous (coal-tar) coatings. Plastic coatings have high thermal stability whereas bituminous coatings have low thermal stability.

Damage to the pipeline insulating joints can be avoided if the voltage stresses across them are limited to a level below the maximum voltage tolerance of the mentioned joints, which depends on the type of insulating joint. Some are able to withstand 5 kV when submitted to short-duration voltage stresses. If higher voltage stresses are anticipated, surge arresters should be installed across the insulating joints. In this case the nominal voltage and the energy dissipation capability of the surge arrester need to be appropriately specified.

Damage to the pipeline cathodic protection system (CPS) can be avoided by limiting the pipeline induced electric potential at the point of connection to the CPS to a voltage level that is smaller than the maximum reverse tolerance of the CPS rectifier, which varies by type. If higher voltage stresses are anticipated, surge arresters should be installed. This analysis is usually done for worst-case conditions that typically occur during short-duration disturbances.

MITIGATION METHODS

The choice of an appropriate mitigation method requires a thorough understanding of the relevant parameters and physical mechanisms that influence the pipeline-induced voltage levels. In addition, it is worth noting that some of these mitigation techniques require special caution. For instance, the installation of grounding points at the pipeline can lead to problems with corrosion.

Mitigation of the capacitive coupling disturbances

The following techniques have been used:

- Reducing the electric field produced by the power line;
- Increasing the separation between power line and pipeline;
- Dividing the pipeline in several sections of smaller length; and
- Grounding pipeline above-ground sections.

Mitigation of the inductive coupling disturbances

The following techniques have been used:

- Reducing the magnetic field produced by the power line;
- Increasing the separation between power line and pipeline;
- Limiting the parallelism length between installations; and
- Crossing the installations with angles near 90°.

Mitigation of the conductive coupling disturbances

The following techniques have been used:

- Reducing the short-circuit currents injected into the ground by the power line;
- Reducing the pipeline exposure to ground potential rise; and
- Avoiding the propagation of remote potentials.

SOME TYPICAL RECOMMENDATIONS

Note that these are some generic recommendations that have been used in typical projects. Any application to a specific project must be assessed by a detailed engineering analysis with respect to efficacy and consequences. (Neither the author nor Siemens PTI assume any responsibility about their application to specific cases. Those who use these recommendations do so at their own risk.)

Some design recommendations

- Try to avoid proximity between power lines and pipelines near substations (high short-circuit levels) and regions with high values of soil resistivity;
- Try to locate the crossings as far as possible from overhead line towers (if possible, at midspan);
- Try to do crossings with angles near 90° (the minimum crossing angle should be 60°);
- When power lines and pipelines run in parallel, try to minimize the parallel length and to increase the distance between them;
- Avoid grounding points at the pipeline; they can produce corrosion;
- Reduce risks of electric shock to people by using underground pipelines;
- Install shield wires on the overhead lines when possible;
- Use asymmetrical grounding electrodes at the towers of the crossing span; and
- Reduce the power line protection clearing time when possible.

Some recommendations for installation, maintenance, and operation of a pipeline near a power line

- Keep minimum safety distances between the overhead line conductors, vehicles, and cranes used for the pipeline installation;
- At the construction site, store the uninstalled sections of pipeline transverse to the line direction and far from line towers and conductors;
- Avoid maintenance services during bad weather conditions (thunderstorms, strong winds, etc.);
- Before performing pipeline maintenance services, the electric utility should disable the power line automatic reclosing scheme;
- Pipeline maintenance workers should avoid simultaneous contacts between two pipeline sections that could develop a voltage between them; and
- It is strongly recommended that pipeline maintenance workers use insulating gloves and boots.

REFERENCES

CIGRE Technical Brochure "Guide on the Influence of High Voltage AC Power Systems on Metallic Pipelines", Paris, 1995.

CIGRE Session. 1986. Experience of CHESF concerning interferences between EHV transmission lines and pipelines. Paris. Paper 36-07.

CIGRE Session. 1990. Induced effects caused by overhead transmission lines on metallic structures. Paris. Paper 36-202.

Dalziel CF. 1972. Electrical shock hazard. IEEE Spectrum. Feb. pp. 41–50.

Liege. 1990. Effects on other installations of the injection of short-circuit currents into the ground. 4th International Symposium on Short-Circuit Currents in Power Systems.

Sao Paulo. 1994. Electromagnetic compatibility between electric power systems and other installations. International Symposium on Electromagnetic Compatibility.

Schenectady. 2004. Siemens PTI Course Notes on Electromagnetic Compatibility between Power Lines and Pipelines.

BIOGRAPHICAL SKETCH

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Jose Daconti has worked for Power Technologies International since 2001. He has a MSEE Honors Degree from EFEI- Federal School of Engineering of Itajuba (Brazil) and he is a Cornell University HHH Fellow in the areas of Electric Power Systems and Electric Power Quality. Since 1978, most of his work has been concentrated in the areas of transmission line electrical design and power system electromagnetic compatibility. In 2000, he was nominated a CIGRE Distinguished Member. Additionally, he is an IEEE Senior Member and a Full Member of Sigma Xi (Rensselaer Polytechnic Institute Chapter).

The OCP Pipeline Project in Environmentally Sensitive Areas

Miguel Alemán, Mauricio Avila, Craig Day, and Tim Zboya

The OCP Pipeline (Oleoducto de Crudos Pesados) crosses the eastern Amazon region of Ecuador from the city of Nueva Loja (Lago Agrio, Province of Sucumbios), and crosses the Andes mountain range to reach the Pacific Ocean near the western coastline city of Esmeraldas. This route resulted in a 485 km (301 mile) crude oil transportation pipeline. The project is additionally complemented with offshore facilities. The OCP route, on the western slopes of the Andean cordillera, crosses a highly biologically sensitive zone, which includes both primary and partially intervened forests, in the Mindo–Nambillo Protected Forest. This segment presents an irregular configuration of terrain with steep slopes, instabilities, and a propensity for erosion. In order to protect and conserve these characteristics, the construction process counted on the application of ingenious methodologies, combining innovative processes with manual activities and exacting environmental supervision, which permitted the maximization of environmental control during construction. The description of the studies, environmental and engineering processes, construction aspects, preventive measures and final restoration measures is analyzed in this document.

Keywords: Pipeline, erosion control, ecological restoration, gabions, cable system, culuncos, right-of-way

INTRODUCTION

The OCP Pipeline (Oleoducto de Crudos Pesados) crosses the eastern Amazon region of Ecuador from the city of Nueva Loja (Lago Agrio, Province of Sucumbios), and crosses the Andes mountain range to reach the Pacific Ocean near the western coastline city of Esmeraldas. This route resulted in a 485 km (301 mile) crude oil transportation pipeline. The project is additionally complemented with offshore facilities. This project was build from August 2001 until October 2003. In November 2003, OCP Ecuador S.A. received the operation permit.

On November 13, 2003, OCP obtained from the Environment Ministry, the Environmental License for the Operations Phase after complying 100% with the requirements established by the legal framework of Ecuador for the environment. All of which included the approval of the complementary studies (Emergency Response Plan and Environmental Management Plan, among the most important), and compliance with the conditions of the environmental license for the construction phase.

ENVIRONMENTAL STUDIES

Environmental studies and licensing

Prior to construction an Environmental Assessment Study was completed resulting in the Environmental Management Plan on which the OCP pipeline construction methodology was based. The Environmental Management Plan was approved by the Environment and Energy and Mines Ministries, which issued the Environmental License and Construction Permit (June 2001). Leading-edge environmental protection techniques were used in the construction of the OCP. Furthermore, the oil pipeline is buried in 99% of its length.

In addition to the non-conventional construction methods implemented, erosion control, restoration and re-vegetation measures were also applied throughout the entire OCP pipeline route. The heavy crude

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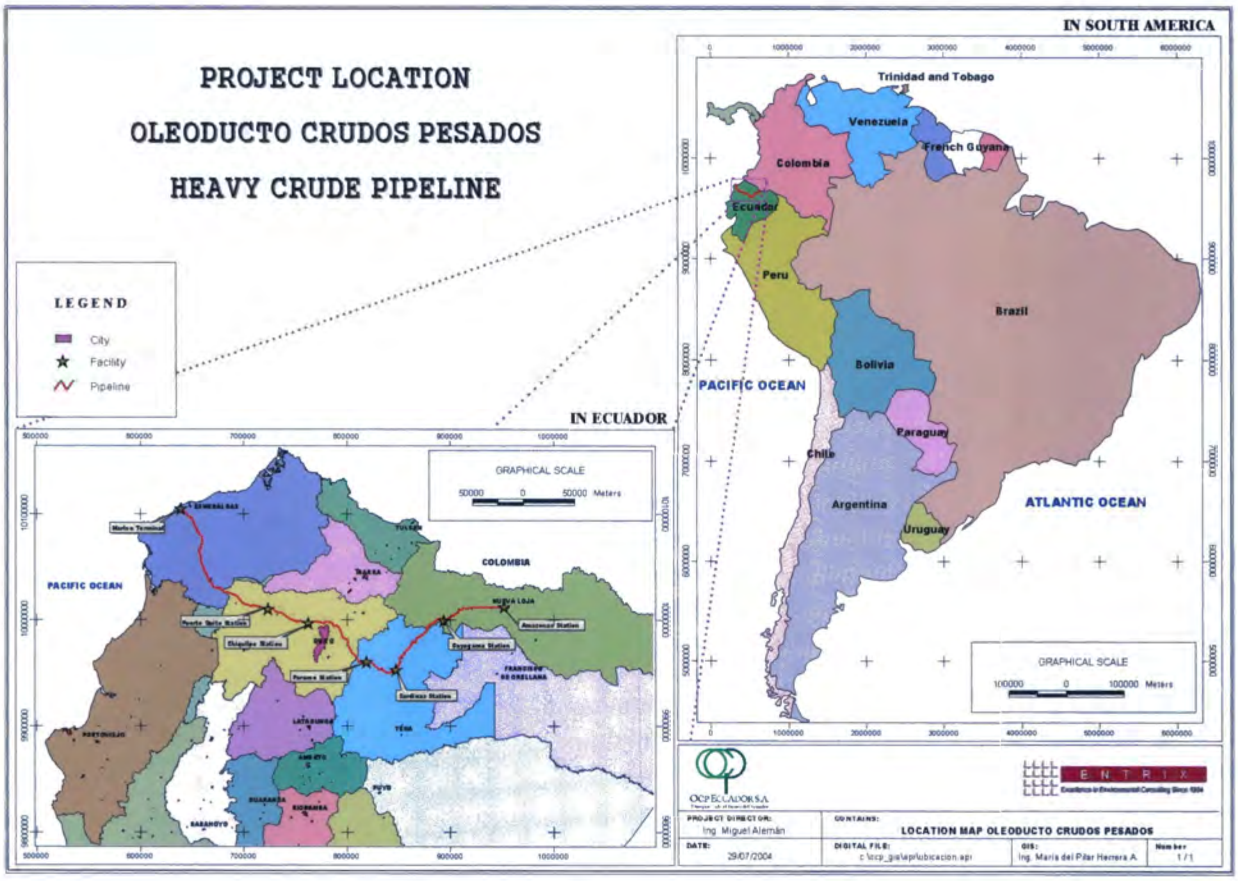

Fig. 1. Project location.

pipeline project was subjected to the strictest environmental requirements in the history of Ecuador. OCP construction activities complied with all the commitments established by the Environmental Assessment Study, the Environmental Management Plan, and the Environmental License, all of which were approved by the appropriate Ecuadorian regulatory authorities (Energy and Mines and Environment Ministries). It is important to note that the above-mentioned studies and plans were reviewed and supported by international environmental consultants engaged by the Ministries.

Fig. 2. Cable system working in Mindo Ridge.

Environmental follow-up and control – construction phase

During the construction phase of the OCP, a program of environmental monitoring, follow-up, and control was implemented to ensure compliance with the Environmental Management Plan. This program was directly associated and worked closely with the Energy and Mines, and Environment ministries. Additionally, the Littoral Polytechnic School (Quito, Ecuador) participated in the program as an external Environmental Auditor. Furthermore, OCP conducted a continuous socio-environmental monitoring program, which was performed by environmental consultant company ENTRIX, Inc., with the participation of CECIA (the Ecuadorian branch of Bird Life International), the National Polytechnic School (Quito, Ecuador), the National Herbarium (Quito, Ecuador) and, for the re-vegetation process, the Jatun Sacha Foundation, a local Non-Government Organization (NGO). The international inspection company, Bureau Veritas in Ecuador audited this continuous self-monitoring program.

OCP construction process was also continually monitored by the ESPOL (Littoral Polytechnic School, Guayaquil, Ecuador) through a regular audit process.

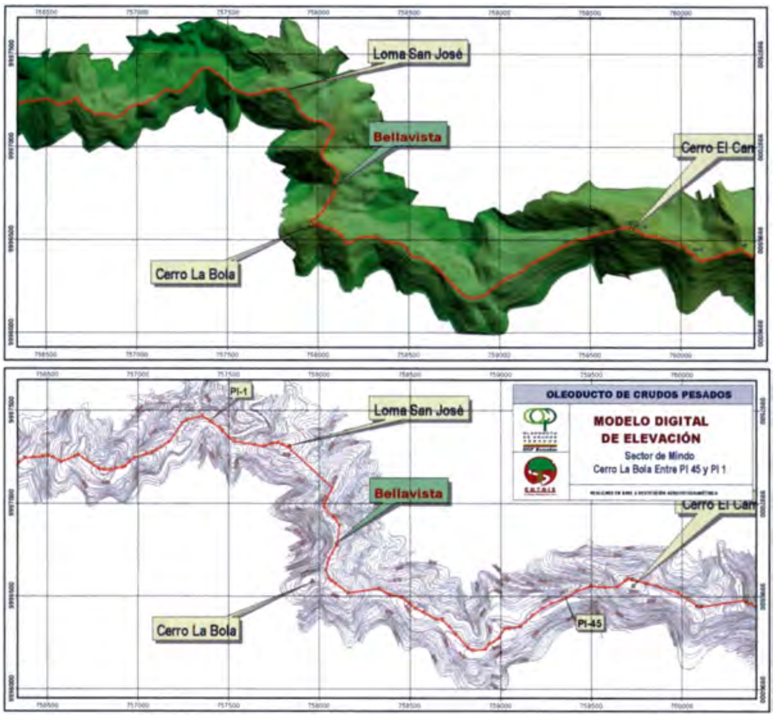

Fig. 3. Mindo Ridge, elevation digital model.

Table 1. OCP environmental compliance rates for spreads

Spread	Compliance percentage
Special Mindo Spread	100%
Spread 4	99.44%
Spread 3	99.02%
Spread 2	98.88%
Spread 1	98.37%

Source: ESPOL, Final Report, October 2003.

The ninth ESPOL environmental audit for the OCP Project was conducted from September 4 to 14, 2003. This audit complemented the eight (8) previous ones, which were conducted periodically throughout the 25-month duration of the construction phase. The results of the Environmental Audit conducted by ESPOL rated the OCP environmental compliance in each of the five project pipeline construction spreads as in Table 1.

Based on the detailed data above, and considering the magnitude, location, and complexity of the project, OCP Ecuador S.A. completed the construction phase with outstanding levels of environmental compliance. These results, insofar as environmental compliance is concerned, are unequaled in Ecuador. In fact, there has been no other project in Ecuador with such a strict Environmental Management Plan and to which were applied such rigorous follow-up, external and internal controls. This has established a milestone for projects in Ecuador.

Description of the Mindo–Nambillo protected forest section

Physical characteristics

The Mindo–Nambillo protected forest is located on the eastern cordillera of the Andes Mountains, north east of the capital city of Ecuador, Quito. The protected forest is located between the Alambi River and Mindo River hydrographic basins, between an altitude of 2650 and 2750 meters (8695 to 9020 ft) above sea level. The topography of the area is typified by the presence of several high mountains joined by narrow ridges with steep lateral slopes ranging between 40 and 55 degrees. The area encompasses forests with high-density fog and humidity and an annual rainfall of over 2900 mm (114 inches).

Biotic characteristics

According to the Preliminary Proposal for a Vegetation Classification System for Continental Ecuador (Sierra, 1999), the Mindo–Nambillo Forest is classified as a Mountainous Clouded Forest, formed by a partially intervened mature forest. This forest, located on the western foothills of the Andes Mountain Range, does not display a large arboreal diversity, but very diverse epiphyte species. The general diameters of the trees range from 100 to 600 mm (4 to 24 inches) (DAP[1]). The natural forest canopy in this sector exhibits a maximum height of 12 m (39 feet), and is generally loaded with moss, which permits trapping and condensing the humidity from the environment. The flora and vegetation are mainly composed of the following:

1 DAP – diameter at chest level.

- The arboreal species present in the zone are: Clusia alata (*Clusiaceae*) "tarqui", Hedyosmum cuatrecazanum (*Chloranthaceae*), Billia columbiana (*Hippocastanaceae*), "arrayán" Myrcianthes rophaloides (*Myrtaceae*), Nectandra laurel (*Lauraceae*), Myrsine cf. andina (*Myrsinaceae*);
- The sub-canopy is represented by trees up to 5 meters (16 feet) high including the "limoncillo" Siparuna lepidota (*Monimiaceae*), Weinmania pinnata (*Cunnoniaceae*), Miconia theaezans. (*Melastomataceae*),
  Tournefortia sp. (*Boraginaceae*);
- The undergrowth is represented by pteridophyte and land aracean; and
- Included on the epiphyte found on branches: the Anthurium giganteum, and Anthurium sp. (Araceae), orchids of the genres Epidendrum sp., Oncidium sp., and Pleurothallis (Orchidiaceae), ferns such as Polypodium sp., Asplenium sp., and Hymenophyllum sp. (Pteridophyta), and among the "huicundos" the Guzmania sp., and Tillandsia sp. (Bromeliaceae).

Construction plans for Mindo

With the unique conditions found in the Mindo-Nambillo zone ("Mindo Zone"), it became necessary to develop "special" construction methodologies that would adapt to the physical limitations, high biological sensitivity, and geological characteristics of the area. In order to obtain, from the Government of the Republic of Ecuador, the Environmental License for the construction of the OCP in the sector of Mindo, a specialized construction plan was developed for application in this Zone.

CONSTRUCTION METHODOLOGY

The physical limitations posed by the topography of the Mindo-Ridge required that the Contractor select a construction methodology that could meet the following criteria:

- Construction must be confined to the restricted the right-of-way and workspace provided for within the Environmental Permit and the physical limitations imposed by the ridge;
- The environmental objectives of the EIS must be met;
- Construction methodology must be able to achieve the technical installation requirements of the pipeline size;
- The pipeline and the associated geotechnical works must be installed according to the requirements imposed by the geotechnical and seismic studies; and

Prior to finalization of the construction plan, a number on construction methodologies were investigated for suitability for use through the Mindo–Nambillo area.

Tram-system

The tram system involves the installation of a small monorail system on which small, powered trams could operate. The small tram is sized to transport both construction materials and personnel along the length of the right-of-way. This system permits the reduction in the size of right-of-way by eliminating the need for large wheeled or tracked vehicles to transport in construction supplies. This kind of system was previously used during the construction of the Villano Pipeline project completed in Ecuador in 1999. This construction methodology was reviewed for applicability to the OCP project and was rejected due to the limitations in the ability of the tram to transport the pipe size required by the OCP and the inability of the tram system to climb the steep grades presented by the terrain in the Mindo area.

Conventional construction on restricted right-of-way

The project used modified construction techniques using conventional construction equipment. Construction techniques developed to minimize the right-of-way required were developed. As the narrow right-of-way through this sector did not permit for "passing lanes" or any additional workspace, construction planning and scheduling was critical to permit the pipeline to be installed while also permitting materials to be moved down the right-of-way.

Cable system

The "cable system" is an aerial cable tram designed to transport materials to the right-of-way. The cable system that was installed on the Mindo Ridge was a system that was specially designed to be applied to the construction conditions on the Mindo ridge. Other cable systems previously have been used on pipeline construction projects in South America to transport construction material across difficult terrain, however, the system employed on the OCP project was unique in that this system permitted lateral inflection points to permit the cable system to follow the meander of the ridge. This kind of transport system had previous proven success in both the mining and forestry industries.

Helicopters

The use of helicopters to transport materials into the construction site is not an unheard of practice in the pipeline construction industry. Large helicopters are employed to fly in pipe and other materials from staging areas into the pipeline right-of-way. The Mindo Ridge area presented a number of obstacles that made this alternative unattractive for the construction phase. The altitude of the Mindo Ridge area decreased the lifting capacity of the helicopters, thus increasing the number of flights required to lift loads. The Mindo Ridge is cloud forest, which, by its very nature, limits the number of hours in the day that has weather suitable for flying. It should be noted, however, even with these limitations, helicopters were employed to demobilize the cable system from the right-of-way. Use of helicopters minimized both the time and the impact that this activity required.

FINAL CONSTRUCTION PLAN

The final Mindo–Nambillo Construction plan combined two of the investigated construction methodologies, cable system and conventional equipment on restricted right-of-way. The construction methodologies were applied in specific areas considering both the physical limitations of the right-of-way, the results of detailed geophysical and geotechnical studies and the environmental sensitivity of the area.

Cable System

The cable system method of construction was applied in areas of very high environmental sensitivity and in area where the ridge was very narrow and had severe grades. This construction methodology was applied over a distance of 5.5 km (3.4 miles), using 9 individual cable systems, stretching end-to-end along the entire 5.5 km.

Advantages of the cable system

The cable system performed a number of functions including transport of materials to the right-of-way, as a sky-crane to position pipe prior to and during welding and as the emergency means of medical evacuations from the ridge. The cable system also permitted the reduction of the working platform width to 7 meters (23 feet) or less by eliminating the need for large conventional pipeline construction and transportation equipment. This reduction was successfully accomplished during construction. At a number of specific locations maximum widths reached no more than 9 m (30 feet), and minimum widths were reduced to less than 4 m (13 feet). The advantages of this system, which were underscored in the study and verified during construction, are the following (Mindo Construction Methodology Rev 5.1):

- The area of impact resulting from the mobilization of construction equipment and the movement of construction materials was greatly reduced;
- The ultimate side of the work platform was reduced since all construction activities were performed manually or where physically possible the use of 'mini' construction equipment;
- This system permits the transportation of resources to the site where construction activities are ongoing without requiring the use of heavy machinery traveling over the work platform;
- No large-volume earthwork is required for opening and leveling of the right-of-way to permit the circulation of transportation and heavy machinery traffic; and
- Avoids the need for constructing intermediate access roads.

Fig. 4. Helicopter working in Mindo Ridge.

The cable system is easily transported, assembled and dismantled using pack animals and human labor. While the cable system permitted the transportation of construction materials over the right-of-way, the pipeline still had to be physically installed in the ground in the right-of-way. To accomplish this, the contractor took the decision to install the pipeline using manual labor throughout the entire 5.5 km sector where the cable system was used. Assisting in the manual construction, primarily pipeline ditch excavation, the contractor utilized mini excavators, that is, excavators that could be transported by the cable system, where space and right-of-way grade permitted. These excavators were used to develop the ditch, drastically reducing the amount of manual labor required to complete this task. These excavators could be moved safely by the cable system to areas where the ridge topography permitted use.

This plan required the simultaneous presence of more than 600 workers in this 5.5 km sector. The advantages of manual works in this highly sensitive section were evident, since it allowed accomplishing the following goals:

- Clearing the vegetation respecting the 7 m width to the maximum;
- Grading consisted only in the removal of the vegetation layer and the little topsoil present (<100 mm), which was stockpiled to the side for subsequent recovery;
- Minimizing amount of earthwork;
- Eliminating multiple passes of heavy machinery over narrow ridges, thus eliminating the potential for side slope instabilities; and
- Excavating a large portion of the ditch manually, and only that amount of soil excavated had to be stored temporarily until the ditch was refilled.

The only equipment and machinery utilized in this section were motors and aerial winches for the cable system, pipe welding equipment, and the mini-excavators, weighing less than 400 kg, for ditching activities. All of these materials were transported via either the cable system or manually by labor or pack-animal assistance.

Assembly and dismantling of the cable system

The section where the cable system was installed between Guarumos and El Campanario Mountains had a length of 5.5 km and was divided into 9 independent-operating sections. At the end of each section, 10 m × 10 m (33 × 33 feet) platforms were graded as installation and work areas, where the main towers and the motors and generators were installed for the operation of the cable system and where materials were transitioned between tower sections. Tower assembly required additional space for anchoring with each tower requiring two or three anchoring areas of approximately 3 m × 3 m (10 × 10 feet) each. In order to obtain the curvature required for the proper operation of the cable and accommodating the different horizontal and vertical variations of the section, intermediate towers were required to be installed that permitted transportation of the materials needed very near the narrow platform work areas.

The towers consisted of framework type-structures with easily assembled, high strength, and light tubular components. The first tower was installed at the last location reached successfully by normal equipment and vehicles. The remaining materials for the towers were transported manually, by men and pack animals, and by the cable system itself. Once construction activities concluded, including the Right-of-Way (ROW) restoration activities, the disassembly of the system followed. Only the sections at each end allowed the transportation and manual removal of materials; in the remaining sections this activity would have involved the manual transit of these materials over recently contoured and revegetated zones. This would have damaged all of the revegetation and geotechnical works, protecting the right-of-way. In order to prevent damage to the completed sections the cable system, towers, and equipment were dismantled, stock piled and removed by light helicopters.

Construction activities

In the cable system segment, the following construction activities were carried out:

- Detailed topographical survey;
- Selective and restrictive clearing of vegetation. Most of the felled trees were reutilized in the construction process and the remaining was chopped up for use during the restoration phase;
- Provisional geotechnical stabilization works;
- Removal and stockpiling of surface organic cover (topsoil);
- Assembly of the Cable System;
- Bending of the pipe in a remote pipe stockpile location;
- Pipe stringing with the cable system. Pipe was delivered pre-bent, with required curvature as originally determined by detailed topographic survey;
- Manual ditching and the use of mini-excavators in specific sections. Ditch width was reduced to a minimum because of the diameter of the pipe in this section was 609 mm (24 inches). Ditch over-widths were constructed only at welding bell holes, as pipeline was welded in the ditch;
- Pipe alignment and welding. Final pipe alignment Backfilling: the pipeline was backfilled with the same material extracted from the ditch excavation. Fill material was compacted with manual equipment. In critical and sloped sectors the soil was mixed with cement and corresponding ditch plugs were constructed. A fiber-optic installation conduit was installed during the lowering and covering process;
- The pipeline was internally cleaned and hydrostatic tests were completed;
- Initial manual recomposition with which the original topographical profile was reconstructed;
- Disassembly of the Cable System; and
- Final recomposition, final stabilization works and revegetation.

Construction using conventional equipment on restricted right-of-way

The Restricted Construction System was applied along two separate sections over a distance of approximately 8 km (5 miles). This construction methodology was implemented in spans that evidenced better geological stability conditions and sufficient workspace for laying the pipeline with conventional pipeline construction equipment. Restricted Construction limited the workspace to a 9-meter (30 feet) wide platform, which allowed selective tree felling with minimal pipeline realignments. Where applicable, this permitted environmentally valuable trees to be saved. This methodology permitted the used of heavy construction equipment, such as backhoes and bulldozers. The movement of pipe to the right-of-way was done using pipe carriers. Pipe carriers are bulldozers that have been converted to carry pipe.

Construction on the restricted right-of-way with heavy conventional equipment required careful construction planning, as the narrow right-of-way through this sector did not permit for "passing lanes." Failure lo plan properly would result in construction and material delivery delays.

ENVIRONMENTAL MEASURES

Complementary environmental measures were defined and applied in this segment of the construction of OCP. Their purpose was to complement the construction process through the use of the Cable System.

Fig. 5. Equipment transportation using cable system.

Fig. 6. Cleared ROW (4 meters).

Fig. 7. Mainly manual works.

Botanical rescue

A specialized team worked on the identification of the vegetation species present in the zone and completed a flora inventory. Prior to and after the vegetation-clearing phase, botanical rescue work was performed that involved felled trees, epiphyte plants found in branches, shrubs, and undergrowth grass species, in addition to obtaining vegetation material and seeds from sylvan plants.

The material obtained from the botanical rescue was delivered to two Ecuadorian institutions. Preserved and dried specimens were delivered for identification and entry in the national biological diversity database of Ecuador, the National Herbarium, and the Ecuadorian Museum of Natural Sciences. Rescued vegetation material and seeds were delivered to the new Quito Botanical Gardens, which in a three-hectare area, makes up a living collection of samples of the richness of the Ecuadorian Andes mountain range, especially of rare and threatened species. The botanical rescue effort made a significant contribution to Ecuadorian scientific development.

Grading plan implementation

Construction through the Mindo–Nambillo Protected Forest was a complex endeavor due to the physical restrictions imposed by the ridge, the constraints of the equipment and commitments made to the Government of Ecuador.

The construction of the OCP pipeline on the Mindo Ridge was very complex due to a combination of factors including (1) limited access to the right-of-way; (2) limited workspace on the ridge; (3) the grade of the right-of-way; and (4) the environmental sensitivity of the areas. To ensure both the technical and environmental requirements of construction were im-

Fig. 8. Gabions for stabilization.

Fig. 9. Slope breakers.

plemented during construction, the use of detailed grading plans were implemented. Grading plans are a common tool often used in the pipeline construction industry to ensure specific environmental objectives of each project are communicated to construction personnel. Grading plans contain a wide range of information, depending on the complexity and variability of the environmental mitigation techniques. Grading plans for the Mindo–Nambillo protected forest were developed by an inter-disciplinary team of environmental, engineering and construction staff. Prior to developing the plans, the inter-disciplinary team conducted a tour of the zone prior to any land clearing activities in order to define the following:

- Measurement of the topsoil layer in the Mindo–Nambillo section, always characterized by layers with a thickness of less than 100 mm (4 inches);
- Location of temporary stabilization works;
- Preliminary location of final geotechnical stabilization works in potentially unstable zones or zones with a ridge width of less than 4 m (13 feet);
- Location of trees to be protected;

Fig. 10. Lateral gabions along the ROW.

- Location of zones with best stability for lateral stockpiling of felled trees and, subsequently, topsoil;
- Location of natural drainages to be protected;
- Location of possible additional areas to be used for stockpile sites; and
- An inter-disciplinary team formed by environmental monitors, specialists in the flora of the area, and construction supervisors accomplished this work. This team served to define the most environmentally sensitive sites as well as proactively plan protection measures to apply to the construction area with sufficient anticipation to solve identified problems.

Selective culunco preservation and cutting

The Grading Plan allowed for the selective cutting and preservation of sensitive tree species, as much as practical, in narrow zones where selective cutting was not possible. A corresponding botanical rescue was conducted in these sections. In addition to the flora in this section, the presence of historical pedestrian paths and mule trails opened during the Colonial Period was detected. These trails join the mountainous Andean zone (Quito) with the Ecuadorian coastline (Esmeraldas). These trails are widely known as "culuncos" and their historical value required their preservation as much as possible.

The culuncos are basically trails excavated in the ground forming ditches with depths ranging from 1 to 3 meters (3–10 feet), an approximate width of 1.5 meters (5 feet), and with almost vertical walls. It has been noted that these trails have deepened over time by erosion mechanisms due to the area's high rainfall. All of the culuncos were mapped and identified with the purpose of defining those that would be affected by the construction process. Mapping of these culuncos confirmed that these trails generally run parallel to the pipeline, but in certain sections cross or run directly under the Right-of-Way and the construction platform.

The culuncos running parallel to the pipeline were preserved through the following measures:
- Initial expert assessments to perform archaeological rescue;
- At zones nearer the pipeline, underpinnings and even filling the section with structures made up of soil-filled sacks protected the culuncos;
- For culunco sections where transit of people and materials was required, the base was protected with wood (generally tree-trunks crossing over the trail);
- Soft-slope transitions were implemented between the right-of-way and the culunco for easy access;
- The construction process excluded the use of culuncos as soil storage sites;
- Training of personnel in the care and preservation of these trails; and
- In a very small number of those cases where the culuncos were directly under the construction platform and OCP was unable to avoid significant disturbance to the trails accurate records, mapping and other historical mitigation methods were performed.

Temporary geotechnical works

As previously mentioned, this zone is characterized by a high rainfall index, which could affect the construction process through erosion phenomena or the loss of excavated material towards the natural drainages of the zone. Rainfall can also produce slope instability by saturating the un-vegetated or unprotected soils on the right-of-way. The following temporary geotechnical works were proposed and executed for environmental protection purposes:
- Construction of wooden lateral barriers (tablaestacados) for the temporary storage of soil and topsoil. Many of these stockpiles were covered and protected with plastic sheeting;
- Construction of "herring bone" barriers (tablaestacados in Y layouts) to contain the soil excavated from steeply sloped zones;
- Construction of sediment traps (sediment barriers) that were located in the main channels of natural drainages;
- Construction of slope breakers in steeply sloped sections with the purpose of redirecting surface runoff off of the right-of-way to safe areas; and
- Temporary protection of the right-of-way during periods of heavy rain by the installation of protective plastic covering over both the cleared right-of-way and open pipeline ditch.

Fauna monitoring

A special faunistic and ornithological monitoring plan was implemented in the Mindo–Nambillo Protected Forest, in order to detect and document in detail any variations in the diversity of the representative fauna groups in the zone. This process was performed in order to objectively assess possible impacts resulting from the construction phase. A specialized technical team performed the monitoring process that compiled data involving species composition, diversity and abundance in the OCP pipeline area of influence during construction. The data were collected by means of sampling techniques and statistical inventories. The first faunistic and ornithological monitoring campaign was conducted prior to the beginning of construction activities, its purpose focused on obtaining baseline reference data upon which future comparisons would be made. Weeklong monitoring campaigns were conducted every 4 months during the construction phase. After the construction phase and into the operational phase, detailed monitoring campaigns are being conducted on a monthly basis with durations of up to three weeks. The results obtained to date evidence that the prevention and mitigation measures implemented for the construction phase have minimized the environmental impact.

RESTORATION OF THE RIGHT-OF-WAY

The restoration of the OCP construction affected areas involved the development of the Right-of-Way Clean-up and Restoration Procedure and the Special Revegetation Plan for the Mindo–Nambillo Protected Forest. Both of these documents served as instruction manuals for the restoration of the pipeline's construction affected areas and platform.

Restoration

Restoration is the process by which the terrain is brought to conditions similar to the original, providing mitigation methods and installations aimed at preventing any erosion and reducing instability risks once the pipeline enters into operation. The restoration process involved three clearly defined phases, as follows:
- Recomposition;
- Construction of final stabilization and erosion-control works (final geotechnical work); and
- Re-vegetation.

Recomposition

Recomposition involved returning the soil to the location where it was originally removed from, attempting as much as possible to recover initial topographical profiles. In the Mindo–Nambillo zone, all the topsoil stored was returned to its original location, spread, and compacted. The vegetation layer was also recovered and spread uniformly over the entire width of the construction affected areas and platform. All of this work was performed by hand. Finally, all the wood from felled trees was chopped up in dimensions smaller than 300 mm (12 inches) and dispersed over the right-of-way to promote its decomposition and assist the development of the species of the zone.

Final geotechnical work

The final geotechnical work consisted of the construction of stabilization and erosion control measures. The stabilization measures implemented were the following:

- Gabions: in the areas where the pipeline crossed through very narrow ridges, right-of-way stabilization was achieved through the installation of gabions along the right-of-way;
- Transversal wood supports: transversal wood supports were constructed in several zones with steep slopes over which soil was deposited until these supports were covered completely;
- Gabion mats and pipe anchors: the seismic and pipe stress design of the OCP pipeline required that the pipeline be installed at specific minimum pipeline depths. Where these required depths could not be achieved, the pipeline was provided suitable support through the installation of gabion mats and pipeline anchors; and
- In areas where the pipeline crossed potentially unstable soils in sectors where Conventional Construction on restricted right-of-way was used, steel piles were driven to increase the soil stability of the sector.

The following erosion control measures were used:

- Slope breakers: these are ditches that serve to remove surface water before it starts the erosion phenomena; the longitudinal slope of these ditches is less than 5%. Considering that the material of the zone is composed of volcanic ash and permeable sands, the slope breakers used in this zone were lined with waterproof geotextile fabric, which prevented water filtration, and over which an organic soil layer was placed before beginning re-vegetation. Finally, these breakers were covered with biodegradable mantles (jute), which prevented erosion from falling water drops and fostered vegetation growth;
- Lateral gutters: when the slope breakers can no longer discharge in stable zones, lateral gutters were constructed to direct the water parallel to the ROW until it reached a safe discharge location. These gutters were lined with polypropylene bags filled with a soil-cement mixture in a 4:1 proportion; and
- Terraces: consisting of wood supports (tablaestacados) that allowed the construction of "steps" with a longitudinal and transversal slope of zero degrees. These structures dissipate surface runoff water energy on very steep slopes, but do allow water circulation and foster vegetation growth.

Taking into account the steep slopes and soil characteristics of this section, slope breakers and terraces were spaced at a maximum distance of 4 m between each other. A system was adopted by which generally only one slope breaker and at least two terraces were constructed.

Revegetation

The Mindo–Nambillo Protected Forest Special Revegetation Plan involved two re-vegetation phases:

- Planting or seeding of grass material; and
- Planting or seeding of arboreal and shrub material.
- The planting of herbaceous material was performed by means of two processes:
- Planting of climbing vine of the *Paspalum sp.* species "nudillo" and turf of the *Panicum polygonatum* species (rabbit-tail), with an average density of 250 mm (12 inches) between each; and
- Planting of seeds of the *Phaseolus polyanthus* species "gualea," which were placed in small holes separated 300 mm from each other or through broadcast seeding (scattering seed).
- Sixty days after the grass species were planted and when sprouting and initial development were observed, the planting of tree and shrub species at 3 m (10 feet) spacing, starting 1 meter away from the axis of the pipeline was conducted.

Attention to landslides

Given the high sensitivity of the zone, seventy lateral landslides that affected the steep transversal slopes occurred during the construction phase. Of these less than twenty surpassed 20 meters (66 feet) in length. In nearly 90% of the cases, the landslides occurred after heavy rains and due to water accumulation in temporary soil storage sites.

The stabilization measures applied for the landslides were the following:

1. In landslide zones with slopes lower than 30% slope, breakers and terrace systems were constructed. Both were subsequently re-vegetated with Paspalum sp. "nudillo" vine and "rabbit-tail" (Panicum polygonatum) turf, and, in addition, trees and shrubs were planted at a distance 3 meters from each other;
2. In landslide zones with slopes surpassing 30%, the double net system was adopted. The double net system utilizes two types of geo-materials: (1) "pocket net" and (2) geo-grid. "Pocket net" is a geofabric that has pockets capable of holding soils, thus permitting re-vegetation on steep slopes. "Geo-grid" is a high strength geo-material used to provide support by anchoring the pocket-net. Organic soil was placed in the pockets together with "nudillo" vine or "rabbit-tail" turf. In these cases, all workers conducted these activities equipped with safety harnesses; and
3. In inaccessible slopes that could not be reached with safely with adequate safety equipment, re-vegetation was conducted with broadcast seeding of the species "gualea."

Fig. 11. ROW: restoration.

Fig. 12. Geotechnical works.

EVALUATION OF RESTORATION 6 MONTHS AFTER CONSTRUCTION

Most of the restoration work executed in the Mindo–Nambillo zone had concluded by the end of 2003, and mid-2004 assessment results are presented below:

Recomposition and geotechnical work

The recomposition and geotechnical work in this zone were performed up to the beginning of the winter season, and the quantitative evaluation of this work is being made as a result of the stability problems that have occurred since then.

The problems that have arisen in this zone are the following:

1. Two landslides originating on the flanks of the ROW;
2. Appearance of cracks in the culunco that borders El Castillo Mountain;
3. Deterioration of a few terraces;
4. Cattle traffic in sector causing deterioration of geotechnical works; and
5. Erosion at a specific location.

These problems arose in the first two months after the conclusion of the recomposition and were immediately attended to and completed by the fourth month, after which no similar problems have arisen. This is positive evidence that the measures taken were highly effective. The maintenance currently performed is preventive involving periodic clean up of slope breakers and the maintenance of access trails.

Revegetation

After planting and broadcast seeding work was concluded, two phases involving the evaluation of germination and the re-vegetation quality were performed. The second phase was executed three months after the first.

The first monitoring phase obtained the following results:

1. Vegetative cover percentage less than 60% with good germination of grass vegetation;
2. The presence of "introduced" tree vegetation in a 2 km (1.2 miles) long span that should have been removed;
3. The presence of the introduced grass species known as kikuyo (*Pennisetum clandestinum*), scattered at several locations on the ROW. It is believed that the species entered with "nudillo" or "rabbit-tail" turf, undetected by the quality control measures; and
4. Low coverage in the areas of approximately 70 landslides.

The second monitoring phase obtained the following results:

1. A vegetative cover percentage near 80% and exceeding that amount in many locations. The 80% figure was established as vegetation cover limit for the acceptance of the vegetative process as good; and

Fig. 13. Successful revegetation and reclamation (Date 08/2004).

Fig. 15. Guarumos Sector (Date 08/2004).

Fig. 14. Castillo sector (Date 08/2004).

2. Vegetation cover exceeding 80% in approximately 50 of the landslides.

Long-term monitoring

OCP closely monitors the right-of-way through the Mindo–Nambillo Protected Forest. Environmental monitors walk the entire right-of-way through this sector on a weekly basis to monitor the success of vegetation, the condition of the erosion control and geotechnical works and to look for evidence of slope instability.

OCP also uses a number of tools to monitor the stability of a number of steep slopes and the stability of gabions stabilizing the right-of-way. These tools include high accuracy survey benchmarks and tilt control points. These tools provide the OCP will additional tools to anticipate problems in order to implement preventative measures.

CONCLUSIONS

The systematic environmental controls developed and implemented during the OCP Project construction phases fulfilled the objectives of the execution phase of the project, which were to ensure that all principles, procedures, and applications contained in the Environmental Management Plan of OCP were implemented and in compliance with all requirements of the relevant approvals and licenses.

New construction techniques devised and implemented in Mindo–Nambillo Protected Forest, including the application of cable systems; unique geotechnical stabilization techniques; gabions; cables and soil concrete; erosion mitigation; and other methods provided measures, in highly sensitive zones, that resulted in the reduction of construction footprints, mitigation of geotechnical instability, and allowed for a proven rapid environmental recovery of the area.

The botanical inventories completed, orchid rescues, ornithological and faunistic monitoring resulted in significant contributions to the biological database increasing relevant scientific knowledge of this sensitive zone in Ecuador. This information is now permitting NGO's to continue their investigations in specific areas, and fosters conservation efforts in this important area that is becoming greatly affected by agricultural and cattle raising activities.

On November 13, 2003, OCP obtained from the Environment Ministry, the Environmental License for the Operations Phase after complying 100% with the requirements established by the legal framework of Ecuador for the environment. All of which included the approval of the complementary studies (Emergency Response Plan and Environmental Management Plan, among the most important), and compliance with the conditions of the environmental license for the construction phase.

REFERENCES

BIRDLIFE International. 2004. "Conserving the Globally Threatened Black breasted Puffleg."

CECIA. 2001–2004. Ornithological Monitoring Monthly Reports, "Informe Mensual del Monitoreo Ornitológico realizado en la zona de Guarumos – Santa Rosa."

ENTRIX. 2001. Environmental Impact Study and Environmental Management Plan of the Heavy Crude Pipeline (OCP) "Estudio de Impacto y Plan de Manejo Ambiental del Oleoducto de Crudos Pesados."

ENTRIX. 2003. Final Socio-Environmental Monitoring Report – OCP Project. " Informe Final de Monitoreo Socio Ambiental – Proyecto OCP."

ENTRIX. 2004. Monthly socio environmental monitoring report – OCP Project. " Monitoreo del Éxito de la Revegetación, Monitoreo Ornitológico y de Obras Geotécnicas."

ESPOL. 2003. Environmental Audit for the OCP Project Construction Phase – 9 cycles. "Auditoria Ambiental para la Fase Constructiva del Proyecto OCP – 9 ciclos."

OCP – ENTRIX – Techint. 2003. OCP Technical Specifications for Construction "Especificación Técnica de Construcción del OCP" 2745-Z-IA-0010, Special Re-vegetation Plan for the Mindo–Nambillo Protected Forest "Plan especial de revegetación del bosque protector Mindo Nambillo." Third approved revision.

OCP – Techint. 2001. Construction Methodology for Mindo, "Complementary Report on the Mindo–Nambillo Protected Forest and the Basin of the Upper Guayllabamba River, Metodología Constructiva para Mindo, "Informe complementario Bosque Protector Mindo–Nambillo y Cuenca Alta del río Guayllabamba."

Sierra, Roberto. 1999. Preliminary Proposal for Vegetation Classification System for Ecuador.

Techint. 2002. OCP Technical Specifications for Construction "Especificación Técnica de Construcción del OCP" 2745-L-SP-20085, Right-of-Way Clean-up and Restoration "Limpieza y restauración del derecho de vía." First approved revision for construction.

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Part IV
Cultural

Discovery and Recovery of Prehistoric Human Skeletal Remains from the Guardian Pipeline Corridor, Kendall County, Illinois

Patrick Robblee

Responding to discoveries of human skeletal remains during federally authorized construction projects is a complicated and time-consuming process with the potential to delay project schedules and increase costs. Finds of human skeletal remains require close coordination between the project sponsor and federal, state and local authorities, consultation with the property owner, and consultation with next-of-kin, lineal descendants, or culturally affiliated groups prior to recovery and disposition of the remains. The process becomes increasingly complex when the find occurs on rights-of-way acquired through condemnation and where the landowner is uncooperative with the process. This paper describes the discovery and recovery of prehistoric human skeletal remains from a condemned easement on private property during construction of a Guardian Pipeline, LLC (Guardian) natural gas pipeline in Kendall County, Illinois. Guardian's response to the find exemplifies the utility of pre-planning for discovery situations. The find triggered a series of consultations with federal and state agencies, local law enforcement officials, the property owner and Indian tribes regarding the recovery and treatment of the remains. The consultations involved protracted discussions regarding legal jurisdiction over the remains, and established a precedent for project sponsors to recover remains from easements on private property in Illinois, without the consent of the property owner. The consultations ultimately led to the scientific recovery of the remains through archaeological data recovery, and curation of the remains with a state museum repository.

Keywords: Cultural resources, archaeology, Illinois, National Historic Preservation Act, unanticipated finds plan

INTRODUCTION

In October 2002, archaeologists working for Guardian Pipeline, LLC (Guardian) recovered human skeletal remains and associated artifacts from a single prehistoric burial located along the Fox River in Kendall County, Illinois. Guardian discovered the site (11KE428) in August 2002 during construction of a new, federally authorized, natural gas pipeline. The find occurred on private property within a right-of-way easement acquired by Guardian through eminent domain. The discovery of the remains resulted in a temporary suspension of construction activities in the site vicinity, followed by a series of consultations with federal, state, and local authorities, the property owner, and Native American tribes to plan for the recovery and disposition of the remains. The consultations led to the scientific excavation of the remains through archaeological data recovery (Walz and McGowan, 2003). Construction of the pipeline in the site vicinity resumed with the approval of federal and state authorities following the excavation of the remains. The recovered materials subsequently were studied over a period of several months, and then curated with a state approved repository at the direction of state authorities.

This paper describes the discovery and recovery of the human skeletal remains from Guardian's pipeline easement. It provides a time line for the completion of this process from the initial discovery of the re-

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mains through their curation. The paper discusses Guardian's efforts to obtain approval from state authorities to excavate the remains without the written consent of the property owner, normally a requirement under Illinois state law. Finally, it summarizes the findings from the excavation.

THE GUARDIAN PIPELINE

Guardian's pipeline measures approximately 228.2 kilometers (141.8 miles) in length and trends generally north from Joliet, Illinois, to Ixonia, Wisconsin (Fig. 1). The pipeline extends about 147.4 kilome-

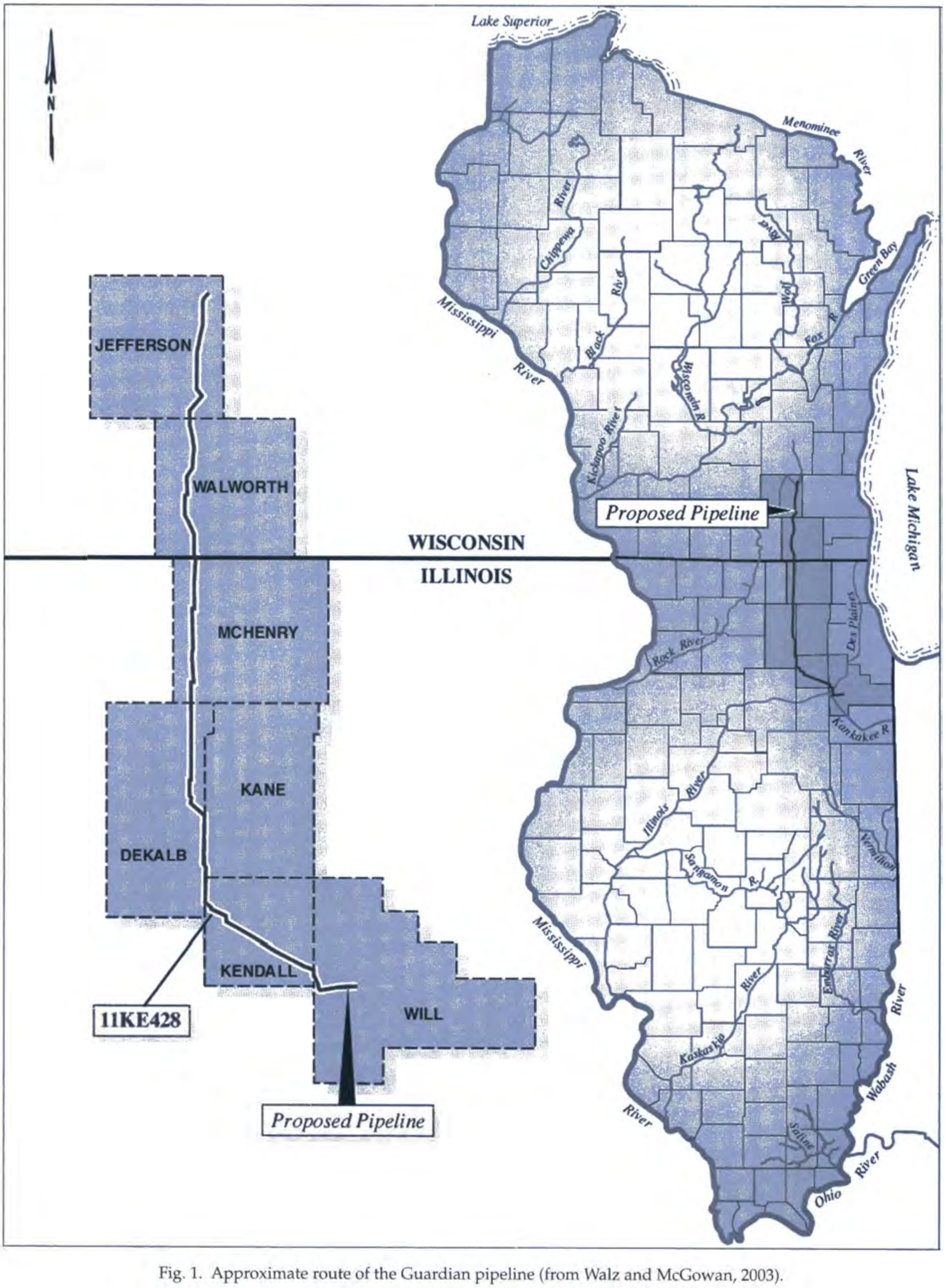

Fig. 1. Approximate route of the Guardian pipeline (from Walz and McGowan, 2003).

ters (91.6 miles) though Will, Kendall, DeKalb, and McHenry counties, Illinois, and another 80.8 kilometers (50.2 miles) through Walworth and Jefferson counties, Wisconsin. The Guardian Pipeline interconnects with several other pipeline systems, which supply natural gas to markets in northeastern Illinois and southeastern Wisconsin.

Prior to building its pipeline, Guardian required authorization (a Certificate of Public Convenience and Necessity) from the Federal Energy Regulatory Commission (FERC), the federal agency that regulates the delivery and sale of natural gas in interstate commerce pursuant to Section 7(c) of the Natural Gas Act [15 USC 717]. FERC's authorization of the project provided Guardian the right of eminent domain to acquire the necessary easements across private property to build the pipeline. Although Guardian attempted to negotiate easements with private landowners along the pipeline route, in some cases it was necessary to exercise the eminent domain powers to secure a continuous right-of-way.

As part of their review of the project, FERC required Guardian to conduct an archaeological survey of the right-of-way prior to pipeline construction. The survey was designed to satisfy the requirements of the National Historic Preservation Act (NHPA) [16 USC 470] and the National Environmental Policy Act (NEPA) [42 USC 4321] regarding affects to the cultural environment. Section 106 of the NHPA requires federal agencies, such as FERC, to evaluate the effects of the projects they authorize or undertake on historic properties, which are defined as cultural resources that are listed or eligible for listing on the National Register of Historic Places (NRHP; 36 CFR 60.4). NEPA requires federal agencies to manage the impacts of regulated projects on the natural and cultural environments, including impacts to historic resources.

Guardian performed the requisite archaeological survey of its pipeline corridor over a period of two and a half years, between 1999 and 2002, prior to construction of the project. Although many archaeological sites were identified (McGowan, 2002a; Robblee, 2003), none were found in the immediate vicinity of 11KE428. Guardian also prepared a plan for responding to any unexpected finds of archaeological sites or human remains that might occur during pipeline construction. This type of plan is required by FERC to ensure that impacts to archaeological resources are managed adequately over the course of a project, even when the construction area has been examined for evidence of archaeological sites. The plan outlined steps for Guardian to follow in the event that previously unidentified archeological materials or human remains were discovered during construction, including suspension of work activities in the vicinity of the find, notification of FERC and state authorities, evaluation of the find by an archaeologist, and recovery or avoidance of the find if it qualified as a historic property or contained human remains.

DISCOVERY AND RECOVERY OF THE REMAINS

Guardian's discovery of human remains at 11KE428 occurred on August 19, 2002 (Fig. 2). Construction crews observed the remains eroding from the sidewall of the pipe trench after the pipeline was installed within the excavated trench (McGowan, 2002b; Walz and McGowan, 2003). The find triggered provisions of the Illinois *Human Skeletal Remains Protection Act* (HSRPA) (20 ILCS 3440) and its implementing regulations, *Rules for the Protection, Treatment and Inventory of Unmarked Human Burial Sites and Unregistered Graves* (17 IAC 4170), as well as the post-review discovery clause of the Section 106 regulations (36 CFR 800.13). The HSRPA is a state law designed in part to safeguard human remains in unregistered graves located on state or privately owned lands. The act assigns jurisdiction of remains less than 100 years in age to the local county coroner and jurisdiction of all other remains to the Illinois Historic Preservation Agency (IHPA). The post-review discovery clause of the Section 106 regulations requires federal agencies to make reasonable efforts to avoid, minimize, or mitigate adverse effects to historic properties discovered after the Section 106 process is completed.

Immediately following the discovery, Guardian implemented its unanticipated finds plan. Guardian terminated construction in the vicinity of the find, reported the discovery to the Kendall County Coroner and Sheriff's department, and notified the IHPA and FERC. The county coroner and deputies from the Sheriff's department initially assumed jurisdiction over the find and secured the site. The next day, August 20, 2002, the coroner investigated the find with the assistance of a forensics specialist from the Illinois State Police. This investigation involved minimal hand excavation around the remains and resulted in the recovery of 20 bones and bone fragments and a prehistoric lithic artifact. The coroner determined that the human skeletal remains were greater than 100 years in age and turned jurisdiction of the site over to the IHPA. Additionally, and at the direction of the IHPA, the coroner transferred the remains and artifacts that it recovered to Guardian (McGowan, 2002b; Walz and McGowan, 2003).

Working closely with the IHPA and FERC, Guardian's archaeologists subsequently conducted a preliminary site investigation to assess the nature and condition of the find. The archaeologists visited the site on August 21, 2002, recorded the provenience of the burial, and carefully backfilled the pipe trench to cover and protect the exposed remains. The archaeologists also examined the surface of the pipeline right-of-way and the fill excavated from the pipe trench in an effort to determine if additional burials had been exposed by pipeline construction; no evidence for additional burials, however, was uncovered (McGowan, 2002b; Walz and McGowan, 2003).

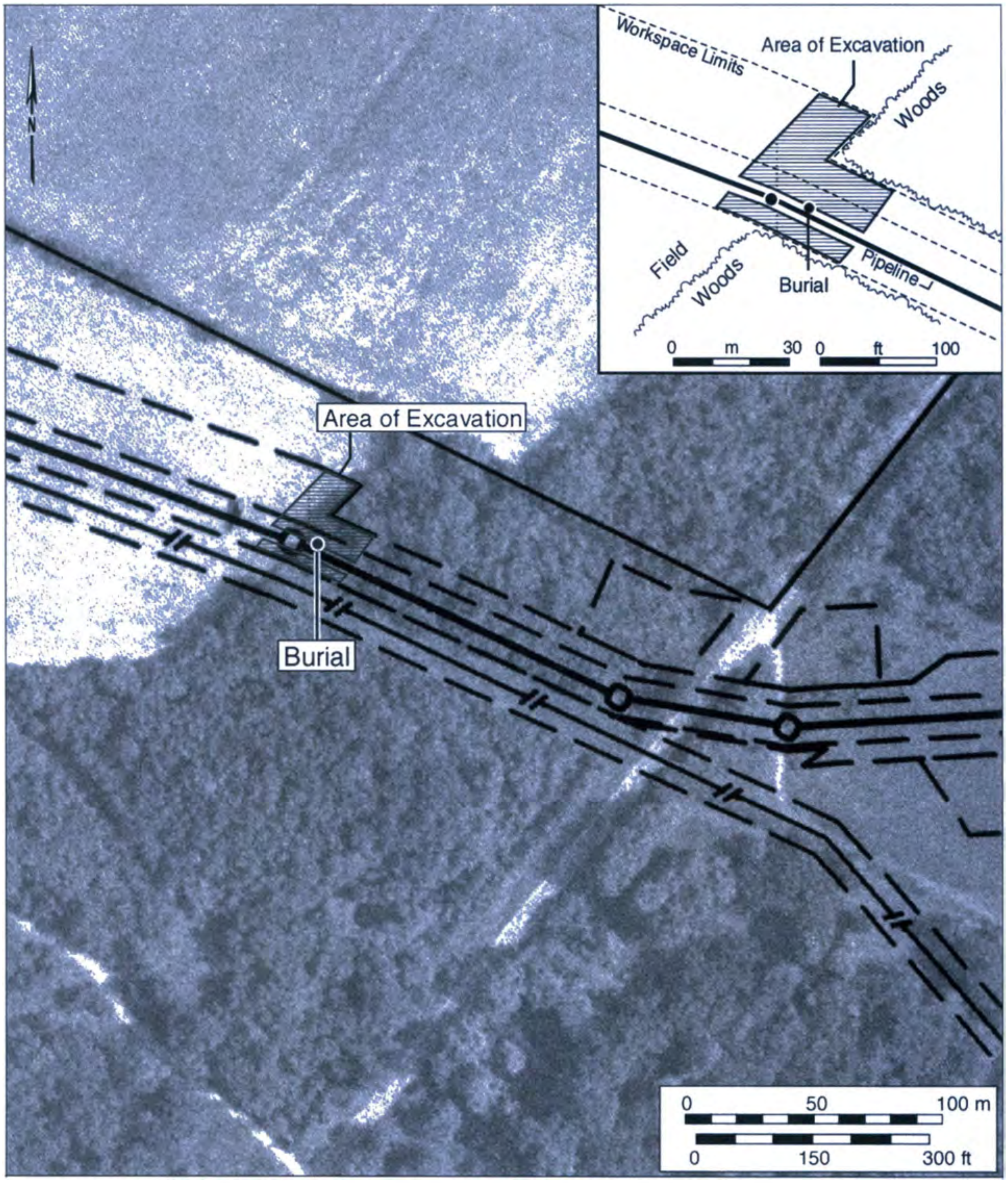

Fig. 2. Plan view of the discovery site (from Walz and McGowan, 2003).

Guardian also retained off-duty deputies from the Kendall County Sheriff's department to provide round-the-clock security on the site. This was deemed essential in the days immediately following the site's discovery because the location of the find was reported in the local media (e.g., Chicago Tribune Online, 2002a, 2002b; Beacon News Online, 2002). Guardian was concerned that media attention on the find could result in illegal looting of the site by artifact collectors or other members of the public. As it turned out Guardian's concerns were prescient and justified; an individual who read about the burial in the local media visited the site area wanting to conduct his own inspection of the find. This individual was turned away from the site by Guardian personnel.

After completing their initial site investigation on August 21, 2002, Guardian's archaeologists spent the next several days preparing a Treatment Plan (McGowan, 2002b). The plan specified methods for documenting and excavating the burial and further investigating Guardian's construction corridor for evidence of other interments or prehistoric features. Guardian filed a draft of its Treatment Plan with the IHPA and FERC on August 26, 2002. The document subsequently was reviewed over the next two weeks, and a final plan was completed and submitted to the IHPA on September 11, 2002. The IHPA approved the final plan in a letter faxed to Guardian on September 17, 2002. Guardian filed the final Treatment Plan with the FERC on September 20, and was authorized by FERC to implement the plan on September 23, 2002, about one month after Guardian assumed control of the site.

Pursuant to requirements in the NHPA, Guardian also reported the find to seven federally recognized Native American tribes with documented historical ties to the project area. Each of these tribes had participated as "consulting parties" in the Section 106 process during the initial review of Guardian's project by FERC. Guardian completed the tribal notifications on August 21 and 22, 2002; six of the tribes requested copies of Guardian's draft Treatment Plan, and one advised Guardian that the site was located outside its traditional territory. Three additional tribes contacted Guardian in response to media reports about the find and requested copies of the draft Treatment Plan. Guardian subsequently sent copies of its draft plan to nine tribes on August 26, 2002. One tribe commented on the plan in a letter to Guardian dated September 11, 2002. None of the other tribes, however, commented on the plan.

Although the IHPA and FERC approved Guardian's Treatment Plan, its implementation initially was delayed by a provision in the regulations for the HSRPA requiring the written consent of the "owner of record" prior to excavation of human skeletal remains from private property [17 IAC 4170.300(b)(9)]. The burial was discovered on a privately owned tract within an easement obtained by Guardian under federal eminent domain power in the United States District Court, Northern Illinois District. Guardian unsuccessfully negotiated with the property owner from September 11 to September 27, 2002 in an effort to obtain the required written consent. When this effort failed, Guardian requested guidance from the IHPA as the state authority with jurisdiction over the remains. The IHPA initially suggested that Guardian's court-approved easement might satisfy the written consent provision of the HSRPA regulations, and requested copies of the court order granting Guardian's easement for review.

On October 3, 2002, Guardian's attorneys sent copies of two orders to the IHPA, the first confirming condemnation of the easement across the tract and the second granting Guardian possession of the easement. The IHPA's legal council subsequently reviewed the orders and issued its opinion on October 16 that the "owner" of the easement for purposes of complying with the HSRPA was Guardian (IHPA, 2002). The IHPA stated that: "While we recognize that there is an underlying landowner, Guardian has been awarded the necessary easements to lay and maintain the pipeline, and 'owns' the pipeline area. Compliance with the National Historic Preservation Act and other applicable laws are integral to the planning and construction for the pipeline, so the work and commitments necessary to document and remove human burials in conformance with the HSRPA would be well within Guardian's rights and responsibilities (IHPA, 2002)." This opinion enabled Guardian to implement its Treatment Plan without the written consent of the actual fee property owner, and also explicitly identified Guardian as the party responsible for care of the remains.

Guardian's archaeologists subsequently conducted the field investigations at the site on October 28 and 29, 2002. The investigations combined both hand and machine excavations to re-expose and remove the burial and to examine Guardian's construction corridor for evidence of other interments or features. The excavations resulted in the recovery of a partial human skeleton (the skull and upper torso) and associated artifacts from the originally documented burial. The remainder of the skeleton appeared to have been destroyed by the previous pipeline construction. The investigations found no evidence for other interments or features at the site. Guardian's archaeologists removed the excavated remains and artifacts to their laboratory for non-intrusive analysis in accordance with the approved Treatment Plan (Walz and McGowan, 2003). FERC authorized Guardian to resume construction in the vicinity of the site on October 31, 2002.

Guardian's archaeologists completed their analysis of the recovered artifacts and remains between November 2002 and March 2003 (Walz and McGowan, 2003), and submitted a draft report on the investigations to the IHPA on March 18, 2003. The IHPA concurred with Guardian's results and recommendations, and also directed Guardian to curate the recovered remains and artifacts at the Illinois State Museum, in a letter dated April 8, 2003. A final report was submitted to the IHPA on May 28, 2003. Copies of the report also were sent on May 28, 2003 to seven Native American tribes at those tribes' request; none of the tribes, however, commented on the report. The final report was filed with FERC on May 29, 2003, and approved by that agency in a telephone call with Guardian on September 11, 2003. Guardian subsequently delivered the recovered remains and artifacts to the Illinois State Museum on November 6, 2003.

RESULTS OF THE INVESTIGATIONS

Guardian's field investigations and laboratory studies yielded significant information about the recovered burial. The investigations identified the skeletal material as the remains of one adult of indeterminate sex. Morphological characteristics on the skull

Fig. 3. Artifacts recovered from 11KE428: a–b, Durst Stemmed projectile points; c, bifacial end scraper; d, deer antler tine; and e, modified mussel valve (from Walz and McGowan, 2003).

implied that the remains were male, but the data were equivocal. Observations of the remains, particularly of the teeth, skull, face, and vertebrae, suggested that the individual died between the ages of 25 and 45 years. No evidence of pathology or trauma was found on the remains. Morphologies observed on the skull were consistent with Native American populations (Walz and McGowan, 2003; Leigh and Blumenfeld, 2003).

Artifacts recovered from the burial consisted of two diagnostic projectile points, a hafted lithic biface, and a deer antler tine. Analysis identified the projectile points as examples of Durst Stemmed, a type that dates from 3500 to 2500 years before present (i.e., during the Late Archaic period) (Fig. 3). The biface was characterized as a scraper, and use-wear identified on the working edge of this tool suggested that it probably was used for scraping hides. The antler tine appeared to be a pressure flaking tool used for lithic reduction, but no evidence of use-wear was found on this specimen. Collectively, the recovered artifacts appeared to represent a hunting tool kit intentionally interred with the individual. The recovery of this kit in association with the human skeletal material further implied that the deceased was male (Walz and McGowan, 2003).

Excavations at the site also resulted in the recovery of four complete or near complete mussel valves and 25 valve fragments. Analysis revealed that two of the valves were culturally modified; the edges on these specimens were cut and ground to from smooth edges, but the significance of these modifications was not apparent. Neither of the remaining two valves was modified. Three of the complete valves were identified as the mucket species (*Actinonaias* cf. *carinata*), but the fourth could not be identified (Walz and McGowan, 2003).

The recovery of artifacts in direct association with the burial provided evidence for mortuary ceremonialism at 11KE428, but the site does not appear to be associated with the Late Archaic burial complexes defined for the northern Illinois region, such as the Red Ochre, Glacial Kame, or Old Copper complexes. Walz and McGowan (2003:30), the principal site investigators, suggest that the site could "represent a previously undefined Late Archaic burial tradition, a difference in an individual status within these previously defined traditions, or simply an artifact of sampling." Although additional research would be needed to better characterize Late Archaic mortuary patterns in the Fox River region of northern Illinois, the results of the investigation provided significant new data on Late Archaic burial customs in northeastern Illinois.

TIMELINE

In total, the entire process of documenting, excavating, studying, and curating the human remains and artifacts from 11KE428, from discovery through curation, required 63 weeks, and resulted in a construction delay of 10 weeks in the immediate site vicinity; pipeline construction continued uninterrupted outside the site area. The construction delay included a month spent negotiating with the landowner and the IHPA over the written consent provision of the HSRPA. Had the landowner been willing to provide Guardian with written consent to remove the remains, or had previous construction projects established precedent for the removal of remains from easements without landowner consent, Guardian's construction delay in the site vicinity could have been reduced to 6 weeks.

CONCLUSIONS

The excavation of the human remains from the Guardian pipeline easement represents a significant contribution to the archaeology of the Fox River region in northern Illinois. To date, few Late Archaic burials have been documented and excavated in this area. The data collected by Guardian will help archeologists reconstruct Late Archaic mortuary practices in the Fox River region and allow comparisons with Late Archaic burials from other parts of the upper Midwest. Additionally, the excavations established a precedent under the HSRPA for the excavation of human remains from easements during federally authorized construction projects without landowner consent.

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REFERENCES

Beacon News Online. 2002. "Remains part of Indian burial site," August 21.

Chicago Tribune Online. 2002a. "State police remove human skull found in a Kendall County ditch," August 21.

Chicago Tribune Online. 2002b. "Skull is called Native American," August 22, 2002.

Illinois Historic Preservation Agency (IHPA). 2002. Letter dated October 16, from A. Haaker (IHPA) to P. Robblee (NRG).

Leigh, S. and J. Blumenfeld. 2003. "Analysis of Human Skeletal Remains" in Treatment Plan Results from 11KE428 for the Recovery of Human Remains ... [from] the Guardian Pipeline Project by G. Walz and K. McGowan, Public Service Archaeology Program, Urbana, Illinois.

McGowan, K. 2002a. Guardian Pipeline Project Cultural Resource Report 9: Investigations 2000 to 2002 in Illinois. Public Service Archaeology Program, Urbana, Illinois.

McGowan, K. 2002b. Treatment Plan for Human Remains Located ... by the Guardian Pipeline Project. Public Service Archaeology Program, Urbana, Illinois.

Robblee, P. 2003. "Archaeological Investigations for the Guardian Pipeline Project in Illinois," in Illinois Antiquity, 38: 4.

Walz, G. and K. McGowan. 2003. Treatment Plan Results from 11KE428 for the Recovery of Human Remains ... [from] the Guardian Pipeline Project. Public Service Archaeology Program, Urbana, Illinois.

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Large-Scale Cultural Landscapes in Rights-of-Way Management

James H. Cleland

Native American perceptions of cultural landscapes are often informed by shared concepts that envision large-scale cultural geographies. As a result, scales for cultural landscape assessments can range from the relatively local to regional. The appropriate scale of assessment in any given situation is sometimes not readily apparent to rights-of-way managers, to land-managing agencies, or to cultural resource professionals. This uncertainty can be a particular problem for linear projects, which can traverse a variety of potential cultural landscapes of differing magnitudes. This paper focuses on a very large cultural landscape associated with the *Xam Kwatcan* trail system in the desert southwest. In all, this landscape is 160 miles or more in length, encompasses portions of three states (California, Arizona, and Nevada), and traverses the traditional territory of multiple Native American tribes. It incorporates extant trails, associated ceremonial sites, and elements of the natural landscape, including highly revered mountains. The United States segment of the North Baja Pipeline project ran through this landscape for much of its 80-mile length. Recommendations are made for approaches to identify Native American concerns, document landscape elements, and develop treatment approaches within the context of Section 106 compliance.

Keywords: Pipeline siting, cultural landscape, Native American consultation, archaeology, prehistoric trails, cultural resource mitigation, ROW

A REGIONAL CULTURAL LANDSCAPE

Yuman-speaking Native American tribes once occupied most of western Arizona and southeastern California (Fig. 1). Well into the 19th century they farmed, fished, hunted, and gathered wild plant foods in a hyper-arid environment crossed by a "linear oasis," the Colorado River (Stone, 1991). They made war and peace and traveled widely across the desert for purposes of social visitation, religious pilgrimages, and trade (Altschul and Ezzo, 1994; Forbes, 1965; Forde, 1931; Kroeber, 1925). The construction of a regional trail system was a key component of this cultural adaptation (Baksh, 1997; Johnson, 1985; 2001; Cleland, 2004), and many trails still exist in remote parts of the desert. This regional trail system plays an important role in the origin legends of the Yuman peoples. For example, according to Quechan cultural tradition, the *Xam Kwatcan* trail marks the route their ancestors traveled on their way from creation to the present. In fact, their tribal name is derived from the name of the trail (Forbes, 1965: 3–4).

In the lower Colorado River culture area, Native American groups continue to occupy their traditional territories and maintain an exceptionally strong cultural continuity as evidenced by continued use of Native languages, maintenance of oral history, continuity in ceremonial practices, and a strong identification with the land (Baksh, 1997; Bee, 1981; 1983; Woods, 2001; Woods, Raven, and Raven, 1986). This identification with the land and with the cultural landscape creates a significant dilemma for cultural resource managers and project proponents. Essentially, the problem is this:

- The regional trail system is vital in cultural identity and traditional practices;
- Traditional cultural practices, which are ongoing, were practiced on a regional scale;
- These practices left a coherent body of material remains on the desert landscape, connected by the largely extant trail system;

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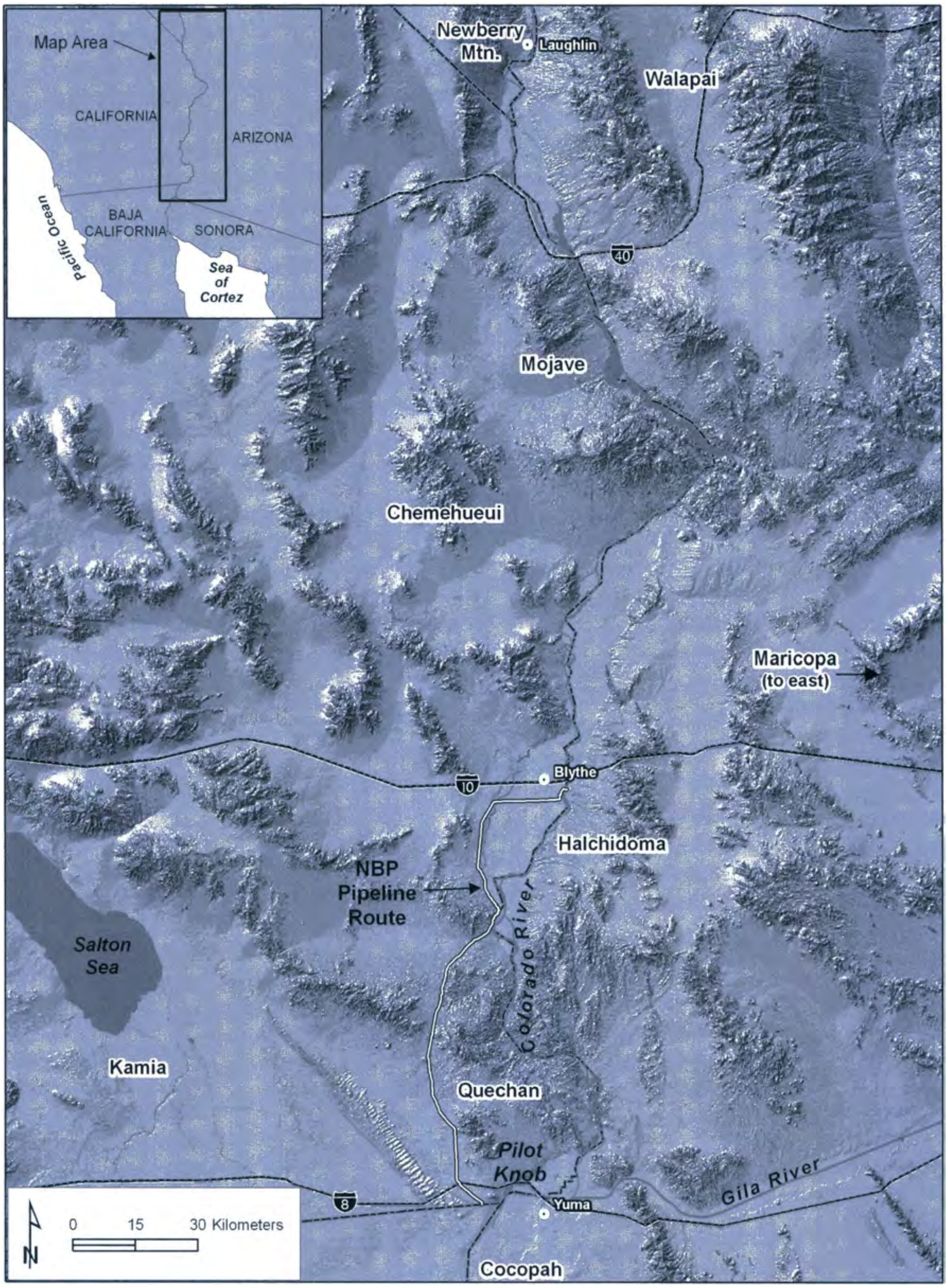

Fig. 1. Native American tribes of the lower Colorado River.

- The trail system connects cultural and natural elements, such as specific mountains, which the Lower Colorado groups identify as culturally significant;
- Cultural elements include the famous large ground figures, or geoglyphs, made on desert pavements, that are unique to the Colorado Desert, i.e., this type of construction is found nowhere else in North America; and
- Traditional Native people assert that all of these elements are inseparable and integral to the continuity of their traditional way of life (Baksh, 1997; Cachora, 1994; von Werlhof, 2004; Woods, 2001).

As will be discussed below; these factors interact to create the need to address an integrated cultural landscape comprised of archaeological sites, natural formations, and trails that is truly regional in scale.

Cultural landscape concepts

The concept of cultural landscapes has been developed in part to address important interrelationships among cultural and natural elements. The National Park Service (Birnbaum, 1994) provides this definition of an ethnographic cultural landscape: "[A cultural landscape in general is] a geographic area (including both cultural and natural resources and the wildlife or domestic animals therein), associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values... [An ethnographic landscape is] a landscape containing a variety of natural and cultural resources that associated people define as heritage resources." Note that the definition of ethnographic landscape emphasizes what *associated people define as important* to their heritage. Similarly, the Park Service has developed the concept of traditional cultural properties to address the values of traditional people: "The traditional cultural significance of a historic property, then, is significance derived from the role the property plays in a *community's historically rooted beliefs, customs, and practices* [emphasis added]. Examples of properties possessing such significance include: a location associated with the traditional beliefs of a Native American group about its origins, its cultural history, or the nature of the world... " (Parker and King, 1990). Again, it is the significance of the resource to a *community's sense of its heritage* that is most critical.

One of the goals of the cultural landscape concept is to expand our understanding of the potential geographic confines of a resource. A National Park Service preservation brief states that "cultural landscapes can range from thousands of acres of rural tracts to a small homestead with a front yard of less than one acre" (Birnbaum, 1994). Despite this, it seems doubtful that anyone necessarily envisioned landscapes of thousands of *square miles* when developing the cultural landscape concept. Yet, if this is the scale of the community's understanding of the resource, we need to develop approaches that are at least cognizant of that understanding.

Impact of Glamis Imperial project

The depth of Native American concern for a regional-level cultural landscape along the lower Colorado River came to national attention beginning in 1997 when the Glamis Imperial Gold Mine was proposed near Indian Pass, California, a very important place on the regional trail system. The cultural resources investigations of the project conducted on the behalf of the Bureau of Land Management (BLM) documented a very high concentration of archaeological features, including geoglyphs, rock rings, scratched petroglyphs, trail segments, ceramics scatters, and lithic scatters in the Indian Pass area (Pigniolo, Underwood, and Cleland, 1997). Archaeological evidence clearly indicated that this area was of special importance for over a thousand years, with use continuing to the very recent past. Moreover, this importance could not be tied to the availability of material resources, such as subsistence foods or usable minerals (see Cleland, 2004). Ethnographic research identified the roots of the concern, as follows:

- The trail system is vital in cultural identity and traditional practices; and
- The Indian Pass area itself is vital in the transmission of traditional cultural knowledge. It is the first in a series of "teaching areas" where young people receive instruction and enlightenment about the tribe's history and belief systems.

Thus the concern was both for a particular place – the Indian Pass vicinity – and for a larger landscape that consists of major and minor ceremonial centers (Altschul and Ezzo, 1994) connected by a prehistoric trail system (Fig. 2). The Glamis Imperial project identified this larger landscape, but did not attempt to address its eligibility for the National Register of Historic Places as a traditional cultural property. Rather, the report assessed these properties based on information in the project area itself and recommended that the area is eligible as a historic district (Pigniolo, Underwood, and Cleland, 1997). In 2000, the Secretary of the Interior ruled against the Glamis Imperial application because of "undue damage" to the environment. This was the first time that a mining project under the 1872 Mining Act had ever been turned down because of environmental concerns, and the impact of the project on the traditional cultural landscape at Indian Pass was the key issue in this unprecedented decision.

Key resource types

The Glamis Imperial project and other recent cultural resources studies in the Colorado Desert indicate that a variety of feature types are important in defining the character of the cultural landscape. The importance of trails has already been discussed. In addition, the following feature types can be particularly important:

- Geoglyphs and rock features – These can be expansive in scale with individual elements exceeding 30 meters (100 ft.) in length (Johnson, 1985). Others may measure only a meter or two across;
- Petroglyphs – These are relatively uncommon in the Colorado Desert, but they typically occur in areas of significance and have been known to have been inscribed into trail surfaces;
- Cleared circles and other cleared areas on desert pavements – Although appropriately sized cleared areas are sometimes called "sleeping circles," the function of these features has been the object of considerable debate and speculation (see Pendleton, 1986; Pigniolo, Underwood, and Cleland, 1997; Schaefer, 1994 for summaries). Cleared circles are most common in vicinities that also contain geo-

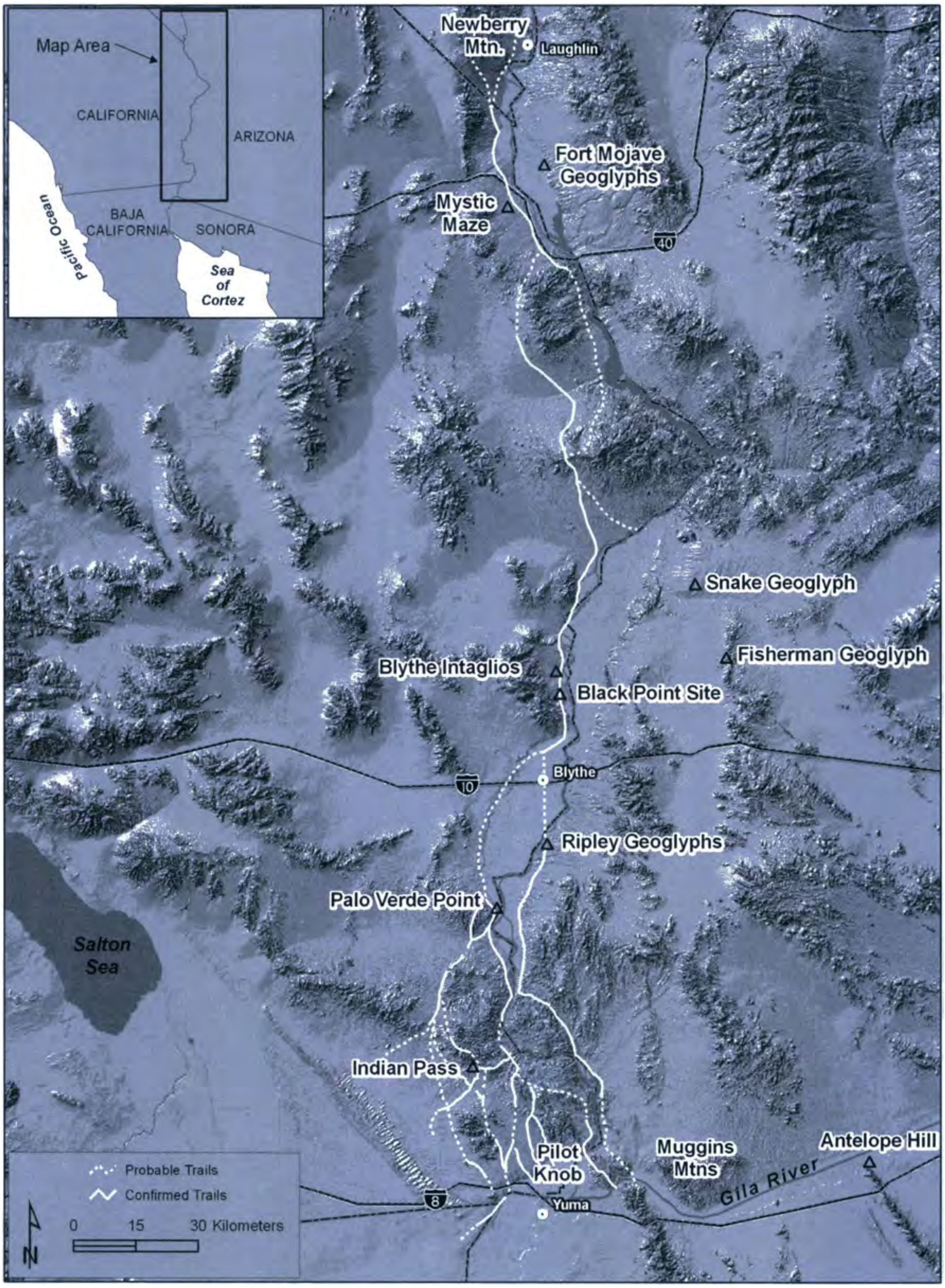

Fig. 2. Elements of the lower Colorado cultural landscape.

glyphs and rock features. Hence, a function associated with individual rituals seems likely; and

- Pot drops – Far from being accidental occurrences, it has been apparent since the 1920s that pots were often used as ritual offerings in areas of cultural significance. Seriations suggest that this behavior has a time-depth of over 1,000 years.

NORTH BAJA PIPELINE PROJECT

The North Baja Pipeline (NBP) was proposed shortly after the Imperial Mine project was denied. While the NBP route avoids by some distance the Indian Pass area, it crosses the international border near Pilot Knob, a well-known traditional cultural property

(Woods, Raven, and Raven, 1986) and the southern terminus of the *Xam Kwatcan* trail. From Pilot Knob, the right-of-way (ROW) parallels the general direction of the *Xam Kwatcan* trail as it progresses north toward the creation mountain. In particular, it crosses Palo Verde Point, the junction of the two main branches of the trail system, according to Native American tradition (Baksh, 1997). A large, well-known petroglyph complex is found at this trail junction (BLM, n.d.; Hedges and Hamann, 1987; White, 1994). In recognition of this significance, NBP conducted an extensive Native American consultation program.

Siting phase

Consideration of cultural resource issues began during the siting phase, and Native American consultation was initiated prior to final route selection. Native American cultural authorities reiterated that the desert landscape and associated archaeological sites form an integral whole of deep cultural significance. They pointed out that much damage has already been done to this cultural landscape and suggested that the project to the extent possible follow existing ROWs that have already been disturbed.

Ethnographic research indicated that, within this regional cultural landscape, the two most culturally sensitive areas were Pilot Knob and Palo Verde Point. Because of this sensitivity, NBP considered major routing alternatives in these areas. In the Pilot Knob vicinity (Fig. 3), NBP conducted cultural surveys of three routing alternatives. Based on Native American input and archaeological findings, the route furthest from this mountain was selected.

Routing was quite constrained at Palo Verde Point (Fig. 4). Very rugged, rocky terrain of the lower slopes of the Palo Verde Mountains dominates the western area, while the Colorado River floodplain to the east is protected as a National Wildlife refuge. State Highway 78 crosses the lower slope just above the floodplain. The Palo Verde petroglyph sites cover much of the point itself. The originally designed route avoided the refuge and the major rock art concentration but would have been extremely difficult to construct. Archaeological surveys revealed several smaller rock art features, geoglyphs, trails (probably part of the *Xam Kwatcan* trail), and cleared circles. Native Americans requested that the route follow the state highway as closely as possible, but safety concerns and highway department regulations would not permit siting in the highway ROW itself. The solution was to propose an alternative route through the wildlife refuge and around the rock art on Palo Verde Point. This alternative, which was probably the least costly to construct, was ultimately selected. Without reference to cultural resource constraints, it is unlikely that an ROW could have been obtained through the wildlife refuge.

Mitigation program

Having recently been acutely involved in the Glamis Imperial project, the BLM and the California State Historic Preservation Office were well aware of the large-scale cultural landscape issues in the NBP project area. NBP determined that an innovative cultural resources mitigation program would help to achieve a consensus under Section 106 of the National Historic Preservation Act. This program focused initially on resource avoidance, particularly avoiding the kinds of features that were known to have special cultural significance, such as geoglyphs, trail segments, and cleared circles. The project managed to avoid geoglyphs and cleared circles completely. Avoidance of trails was more problematic because of their linear nature. To minimize trail impacts, route adjustments were made so that trails were intersected primarily where they had already been damaged by erosion or previous construction.

Trails were given particular attention during all three phases of the archaeological investigation. In the Colorado Desert, prehistoric trails are often associated with rock cairns, rock alignments, pot drops, cleared circles, and other cultural features with particular heritage significance to Native Americans. Eighteen trails were evaluated as eligible for the National Register. During the evaluation phase, the project documented trails up to one kilometer in each direction from the pipeline crossing point; as a mitigation measure this distance was extended to up to 10 kilometers for selected trails. While this might seem like an excessive distance, the effort that is required to map sites using today's technology is not great. A two-person team can readily map two to three kilometers per day. This effort was rewarded by two main benefits, as follows:

- First, submeter Global Positioning System (GPS) units were used in mapping the exact trail locations and the data were converted to GIS files as a long-term management tool useful to the land-managing agencies; and
- Second, only through examination of trails over a long distance could the cultural importance of the trail be adequately understood. Some trail segments are simple branches or diversions, while others represent major transregional routes. Some trail segments have no or very few associated features, while others are associated with abundant features with symbolic meaning.

One trail (CA-IMP-398) was so outstanding that NBP agreed to prepare a National Register nomination form, which BLM will utilize in its site stewardship program. This trail was mapped over a total distance of 19.6 kilometers, and over 325 cultural features were recorded. National Register listing will improve the chances that this trail and others like it in the region will be preserved over the long term.

Due to the very high sensitivity of the Palo Verde Point area, NBP also agreed to undertake recordation of important rock art and other symbolic features in

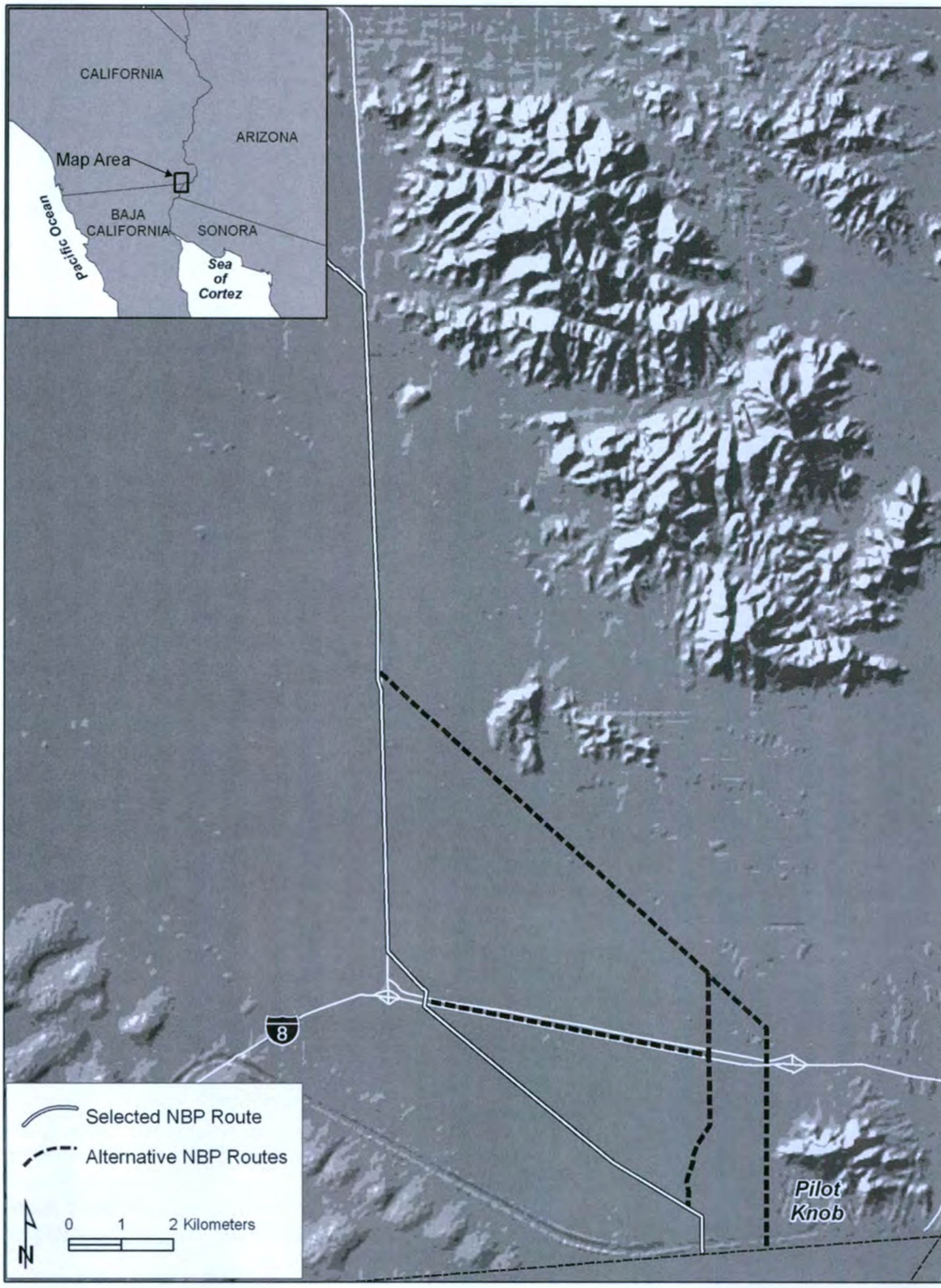

Fig. 3. NBP routing alternatives at Pilot Knob.

the vicinity even though the ROW achieved avoidance of these highly sensitive cultural resources. Again, the primary motivation for this exercise was to improve the long-term preservation of these sites. Although the Palo Verde Point geoglyph cluster is well known, public lands in the Palo Verde area are subject to multiple overlapping jurisdictions. Sites mapped in California by BLM archaeologists from Yuma were not consistently listed in the California archaeological database. By precisely mapping these locations and filing updated site records with all repositories, NBP has made a substantial contribution to ensuring that these unique resources are preserved for future generations.

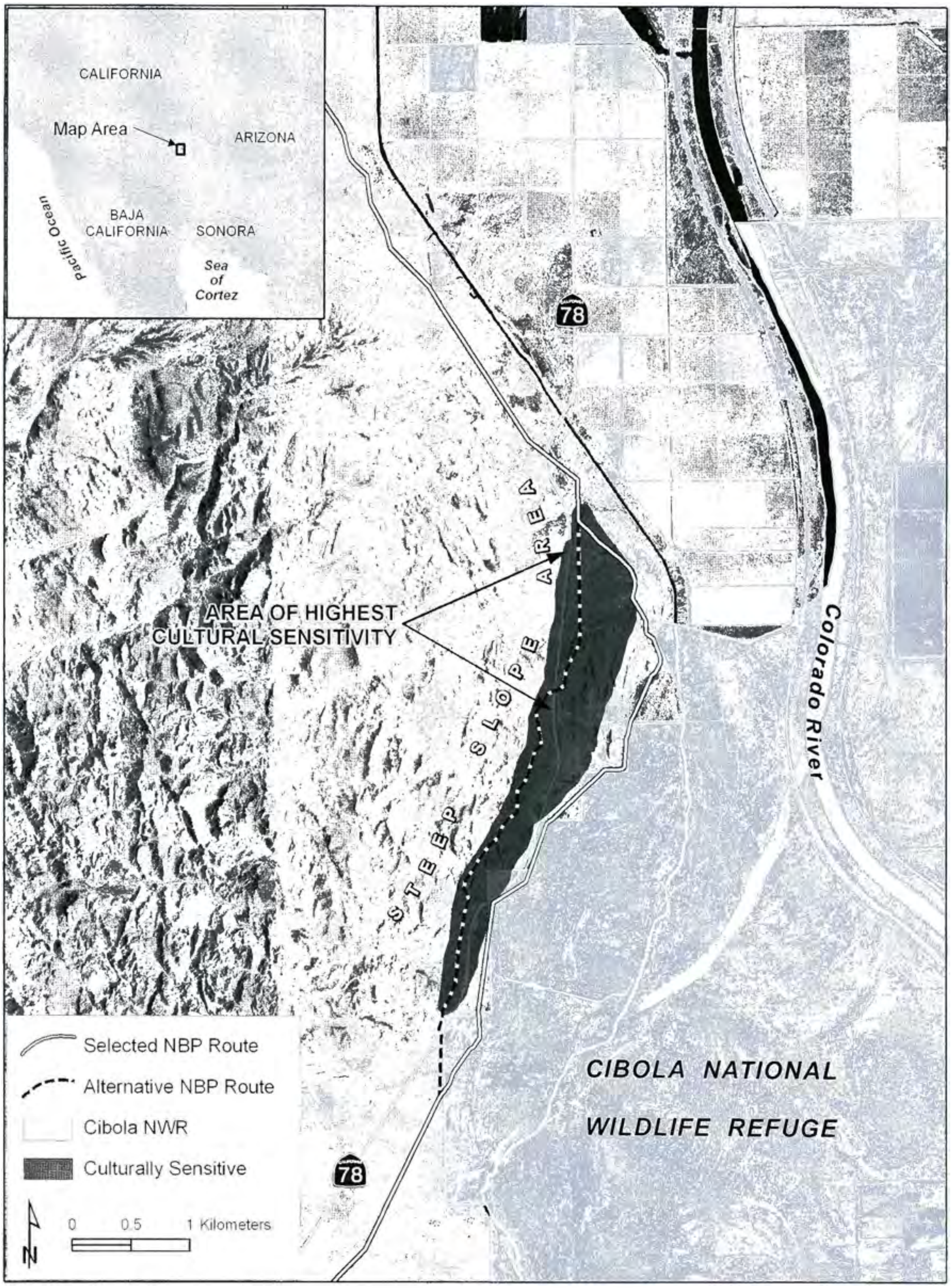

Fig. 4. NBP routing constraints at Palo Verde Point.

The program at Palo Verde Point also included the consolidated recordation for the first time of the entire Palo Verde Point petroglyph complex. As recorded by the NBP team, the complex includes four sites extending over a 2.4-kilometer-long area. These sites contained 520 distinct panels clustered in 41 loci. Each panel was mapped and photographed digitally. In selected instances, digital photos were stitched together and masked at high magnification to create line drawings that are useful in comparative studies. NBP also prepared a National Register nomination form for this unique site.

LESSONS LEARNED

Like Glamis Imperial, NBP did not attempt to assess the National Register eligibility of the regional cultural landscape. It is not clear that such an exercise would be productive due to existing impacts from Interstate Highways, irrigation agriculture, urban development, water control facilities, military installations, and other modern intrusions. NBP did, however, clearly acknowledge the importance of the Native American concerns for this landscape. In so doing, the project went beyond a strict adherence to the concept of limited impacts along the ROW proper. In general, with pipeline projects, the Area of Potential Effects (APE) is defined as the construction corridor itself, and all archaeological mitigation efforts are restricted to the APE. NBP in essence acknowledged that its impact was more regional in nature and addressed that impact appropriately. GPS recordation of major trails and geoglyphs will help protect these resources from future impact, as will the nomination of the most impressive trail to the National Register. The consulting parties found this to be effective mitigation of regional scale impacts.

To achieve consensus regarding the NBP project, all parties needed to be flexible. The Section 106 process is inherently a consultative one. It is not intended to be rigid, although in practice many agencies feel that a certain rigidity is useful. To truly address impacts to regional-level resources, creativity and flexibility are necessary. In the NBP case, the agencies were flexible in applying the Section 106 "criteria of effect"; NBP was flexible in proposing some innovative mitigation strategies; and the Native Americans were flexible in not actively opposing a project that they would just as soon not have seen built. Through early consultation, taking concerns seriously, and "big picture" thinking, the project was able to meet its Section 106 obligations under difficult circumstances without affecting the project schedule.

REFERENCES

Altschul, Jeffery H. and Joseph A. Ezzo. 1994. The expression of ceremonial space along the lower Colorado river. In Recent research along the lower Colorado River, edited by Joseph A. Ezzo, pp. 51–68. Statistical Research Technical Series No. 51, Tucson, Arizona.

Baksh, Michael. 1997. Native American consultation for the Chemgold Imperial Project. Document on file with Bureau of Land Management, El Centro, and Tierra Environmental Services, San Diego, California.

Bee, Robert L. 1981. Crosscurrents along the Colorado: the impact of government policy on the Quechan Indians. University of Arizona Press, Tucson.

Bee, Robert L. 1983. The Quechan. In Southwest, edited by Alfonso Ortiz, pp. 86–98. Handbook of North American Indians, Vol. 10, Smithsonian Institution, Washington, D.C.

Birnbaum, Charles. 1994. Protecting cultural landscapes. National Park Service Preservation Briefs, 36. Washington, D.C.

Cachora, Lorey. 1994. The spirit life of Yuman-speaking peoples: lower Colorado River between Arizona and California. In Recent research along the lower Colorado River, edited by Joseph A. Ezzo, pp. 13–14. Statistical Research Technical Series No. 51, Tucson, Arizona.

Cleland, James H. 2004. The sacred and the mundane: cultural landscape concepts and the archaeological interpretation in the Colorado Desert. Paper presented at the 38th annual meeting of the Society for California Archaeology. Riverside, California.

Forbes, Jack D. 1965. Warriors of the Colorado: The Yumas of the Quechan Nation and their neighbors. University of Oklahoma Press, Norman.

Forde, Daryll C. 1931. Ethnography of the Yuma Indians. University of California publications in American archaeology and ethnology 28(4): 83–278. University of California Press, Berkeley.

Hedges, Ken and Diane Hamann. 1994. The petroglyphs of Palo Verde: a preliminary report. American Indian rock art, vols. 13–14. American Rock Art Research Association, San Miguel, California.

Johnson, Boma. 1985. Earth figures of the lower Colorado and Gila River deserts: a functional analysis. Arizona Archaeological Society, Phoenix.

Johnson, Boma. 2001. Attachment A Cultural resources overview of the North Baja Pipeline Project. In: Appendix D of cultural resources evaluation for the north baja gas pipeline. Prepared by Archaeology Plus, Ivins, Utah. Prepared for Woods Cultural Research, LLC, Evergreen, Colorado.

Kroeber, Alfred L. 1925. Handbook of the Indians of California. Dover Publications, New York.

Parker, Patricia L. and Thomas F. King. 1990. Guidelines for evaluating and documenting traditional cultural properties. National Register Bulletin, 38. National Park Service. Washington, D.C.

Pendleton, Lorann. 1986. The archaeology of Picacho Basin, southeast California. Wirth Environmental Services, Division of Dames & Moore, San Diego, California. Prepared for San Diego Gas & Electric, San Diego, California.

Pigniolo, Andrew R., Jackson Underwood, and James H. Cleland. 1997. Where trails cross: cultural resources inventory and Evaluation for the Imperial Project, Imperial County, California. Document on file with Environmental Management Associates, Brea, California, KEA Environmental, San Diego, California, and BLM, El Centro, California.

Schaefer, Jerome (Jerry). 1994. The challenge of archaeological research in the Colorado desert: recent approaches and discoveries. Journal of California and Great Basin Anthropology 16(1): 60–80.

Stone, Connie L. 1991. The linear oasis: managing cultural resources along the lower Colorado River. Cultural Resource Series No. 6. Bureau of Land Management, Arizona.

Von Werlhof, Jay. 2004. That they may know and remember. Vol. 2: Spirits of the earth. Imperial Valley College Desert Museum Society, Ocotillo, California.

White, William G. 1994. Cast shadows, a lizard's tail, and prehistoric time reckoning: a calendrical petroglyph on the lower Colorado river. In Recent Research Along the Lower Colorado River, edited by Joseph A. Ezzo, pp. 69–79. Statistical Research Technical Series, Tucson, Arizona.

Woods, Clyde M. 2001. North Baja Pipeline Project Native American studies. Prepared for EDAW, Inc., San Diego, and Foster Wheeler Environmental Corporation. Prepared by Woods Cultural Research, LLC, Evergreen, Colorado.

Woods, Clyde M., Shelly Raven, and Christopher Raven. 1986. The Archaeology of creation: Native American ethnology of cultural resources at Pilot Knob. Document on file at EDAW, Inc., San Diego.

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Part V
Wildlife

The Relationship between Birds and Shrubs in a Power Line Right-of-Way

James S. Marshall and Larry W. VanDruff

Previous work has suggested that power line rights-of-way can provide productive habitat for shrub-nesting bird species, a group experiencing serious population declines in the Northeastern United States. This study evaluated the potential for a power line right-of-way managed in an Integrated Vegetation Management regime to support a productive avian community. We monitored both real and artificial nests in a right-of-way near Rome, NY in the summers of 1999 and 2000. Results show that birds nesting in the right-of-way generally prefer shrubs and nest with high success in that habitat. Although the trends from real nests suggest that 100% shrub cover would be most beneficial, nest success and artificial nest data indicate that such cover may result in higher nest predation. A vegetation management program that establishes an intermediate level of shrub cover may therefore provide optimal breeding bird habitat while meeting the requirements of vegetation management on a power line right-of-way.

Keywords: Right-of-way, shrub, bird, nest success

INTRODUCTION

Breeding Bird Survey data show that birds of early successional habitats have experienced severe population declines over the last thirty years, more so than any habitat guild except grassland birds (Askins, 1994). This has been exacerbated in the Northeastern United States by the conversion of abandoned agricultural land into secondary forest, leaving shrub-nesting birds species with ever-decreasing breeding habitat (Porter and Hill, 1998).

Early successional habitats comprise only a tiny fraction of the lands managed by various state and non-governmental conservation agencies. In fact, the largest areas of shrub land in New York are currently in power line rights-of-way. Confer (2002) suggests that more than four times more shrub land is in these rights-of-way than in all other conservation lands combined. This gives right-of-way vegetation managers a unique opportunity to benefit a large number of potentially threatened bird species; an ironic situation given the role usually ascribed to rights-of-way as an agent in habitat fragmentation (Askins, 1994).

In previous work, Marshall et al. (2002) suggested that an Integrated Vegetation Management (IVM) strategy for power line rights-of-way could provide more stable and productive habitat for shrub land birds than more limited strategies like mowing because IVM promotes more stable shrub cover. The current study seeks to expand on these conclusions. Our objectives were first to further establish the positive link between shrub density and the avian community of a power line right-of-way. We also sought to establish the degree to which such habitat provided productive nesting habitat for shrub land birds. Finally, we wanted to investigate the nature of the relationship between right-of-way birds and shrubs to determine if increasing shrub density always led to more productive bird habitat.

STUDY AREA

The two power lines we studied run through a common right-of-way centered north of Rome, New York. The Volney-Marcy line, operated by National Grid (formerly the Niagara-Mohawk Power Corporation), was cleared in 1982 and has since been managed using

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IVM (Finch and Shupe, 1997). The adjacent Fitzpatrick-Edic line, operated by the New York Power Authority, was cleared in 1971. It received selective herbicide treatments from 1971 through 1985, and then mechanical treatments including mowing until 1999. NYPA managers have since resumed selective herbicide treatments.

The right-of-way cuts through a mix of eastern deciduous forest and agricultural land. Agricultural activity in the right-of-way is mostly cattle pasture, with some apple groves and Christmas tree plantations. The rest of the right-of-way is a shrub community or some version of a wetland. Beaver (*Castor canadensis*) ponds and many other areas are flooded and dominated by emergents like cattails (*Typha* spp.). Drier areas on the Volney-Marcy line are dominated by herbaceous species, especially goldenrod (*Solidago* spp.) and aster (*Aster* spp.). Shrub cover, when present, is usually northern arrowwood (*Viburnum recognitum*), nannyberry (*Viburnum lentago*), and various *Spirea* species. Shrub cover was noticeably denser on the Fitzpatric-Edic line, but usually included the same species, with occasional patches of willow (*Salix* spp.) and honeysuckle (*Lonicera* spp.).

We chose nine sites in 1999 and six of those nine in 2000 along a twenty-five mile stretch of the right-of-way. The closest sites were within two miles of one another, but most sites were separated by five miles or more. Each site was surrounded by forest, relatively free of running or standing water, and free of agricultural activity. We established two adjacent 300 m plots at each site, one under each power line. The Volney-Marcy plot had received a consistent herbicide treatment across the full 300 m. We believe the Fitzpatrick-Edic plot was previously mowed and, between 1999 and 2000, received a cut-stump selective herbicide treatment.

METHODS

Vegetation in the plots

To compare the general vegetation present under the two lines in 1999, we measured vegetation in three systematically established subplots within each plot. The subplots were under the center line – one in the middle of the plot, and the other two 50 m into the plot from either end. We established a 5-m radius circle at each of these points and counted all stems above 50 cm within that circle. We followed the same procedure in 2000, but added three new subplots around each original subplot for a total of 12 subplots per plot. The new subplots were 20 m from the originals and equally spaced from each other.

Bird density and nest success

To quantitatively survey avian community composition, we used spot-mapping as described in the International Bird Census Committee guidelines (1970). We used color-coded PVC pipe to establish a grid in each plot. All bird contacts during a survey were recorded on a map of this grid. Ten surveys were done in 1999, and another ten were done in 2000.

We intensively searched for and monitored nests on two plots every morning from mid May to the end of July in 1999, and from mid May to the end of August in 2000. We marked nests with a small piece of flagging 5–10 m from the nest and then monitored each nest every three to four days until fledging or failure. A nest was considered active once an egg appeared and fledged if nestlings disappeared at an appropriate time for that species.

Birds and vegetation

To analyze bird preferences for nest site vegetation, we established 5-m radius circles around nests and did the same vegetation measurements as were done in general vegetation subplots. In 1999, we used the three general vegetation subplots as our measure of generally available vegetation. In 2000, we randomly chose one of the twelve available general vegetation subplots to measure on the same day that we measured the nest vegetation. Each nest was paired with its own general vegetation subplot to reduce spatial and temporal variation in vegetation.

Artificial nests

In 1999, we used three plots not used for nest searching for an artificial nest study. Twenty small wicker nests were placed on the ground under the center line of each of the two lines. They were spaced 20 m apart. Each nest received a *Coturnix* egg and a clay egg. Eggs were placed in nests on 25 May, and then checked on 28 May, 1 June, and 5 June. The fate of both eggs was recorded on each visit.

DATA ANALYSIS

Vegetation differences between the two lines

Vegetation on the two lines was noticeably different from visual inspection. We used the general vegetation subplots to analyze the differences. We categorized each plant species as herbaceous, fern, *Rubus*, shrub, or tree. Shrubs referred to all woody species that when mature grow as multiple stems from approximately the same place. Trees included all woody species that typically occurred as single-stem plants once mature. Although *Rubus* species are generally considered shrubs, we separated them from shrubs in stem counts. *Rubus* stems usually equaled or exceeded all other shrub stems combined, making them a disproportionately important group in the right-of-way.

The selective herbicide treatment of the Fitzpatrick-Edic might have complicated a two-year pooled comparison of vegetation on the two lines. Marshall and VanDruff (2002), however, found no significant changes in vegetation before and after the treatment. We therefore pooled analyses of vegetation for 1999 and 2000, leaving out the data from the 2000 measurements of the original subplots. We then used Wilcoxon signed-rank tests to compare each of the five stem-count classes between the two lines.

Territory and nest differences between the two lines

Marshall et al. (2002) found several bird species with territory and nest density differences between the two lines in 1999. We repeated those analyses with the data from 2000. We used paired t-tests to compare territory densities between the two lines. We standardized density by dividing territory number by plot size to control for differences in plot sizes. The density of one species in one plot thus became one observation. The density of nests in plots was standardized in the same manner, and compared between lines using paired t-tests.

Relationship between birds and vegetation

To evaluate the relationship between birds and vegetation, we compared the vegetation in a 5-m radius circle around each nest to either the general subplot chosen with it in 2000, or a randomly selected subplot if the nest were from 1999. All nests of a species were pooled for the two years. Paired t-tests then compared the 5 stem-count classes around nests and on general subplots.

Nest success

We estimated daily survival probabilities for nests of each species pooled for the two years using Mayfield's (1975) method. We also calculated standard errors for these estimates (Johnson, 1979). We then used CONTRAST (Sauer and Williams, 1989) to compare daily nest survival estimates on the two lines.

For the artificial nests, we simply compare the percent nests surviving between the two lines. The comparisons are based on the number of nests found with both eggs intact on the last day of monitoring. Any nest with missing or damaged eggs was considered depredated.

RESULTS

Differences in vegetation between the lines

General vegetation subplots on the Volney-Marcy line had more herbaceous stems ($p = 0.0002$) and *Rubus* ($p = 0.05$) than subplots on the Fitzpatrick-Edic line. Subplots on the Fitzpatrick-Edic line, on the other hand, had more ferns ($p < 0.0001$), shrubs ($p < 0.0001$), and trees ($p = 0.05$) than subplots on the Volney-Marcy line.

Densities of territories and nests

Several species had different territory densities on the two lines in 2000. Song sparrows (*Melospiza melodia*) were marginally more abundant on the Volney-Marcy line ($p = 0.07$). Yellow warblers (*Dendroica petechia*) were marginally more abundant on the Fitzpatrick-Edic line ($p = 0.09$), as were American goldfinches (*Carduelis tristis*, $p = 0.08$). Three other species were significantly more abundant on the Fitzpatrick-Edic line. These included alder flycatchers (*Empidonax alnorum*, $p = 0.02$), gray catbirds (*Dumatella carolinensis*, $p = 0.03$), and chestnut-sided warblers (*Dendroica pensylvanica*, $p = 0.03$).

No species had higher nest densities on the Volney-Marcy line than on the Fitzpatrick-Edic line. Three species, however, nested more abundantly on the Fitzpatrick-Edic line – yellow warblers marginally so ($p = 0.08$); and alder flycatchers ($p = 0.04$) and chestnut-sided warblers ($p = 0.009$) significantly so.

Relationships between birds and vegetation

A number of species had significantly different vegetation around nest sites than was generally available in the plot. Alder flycatchers nested in areas with marginally more trees ($n = 32$, $p = 0.06$). Gray catbirds had fewer herbaceous stems ($n = 43$, $p = 0.003$), and significantly more *Rubus* ($p = 0.01$) and shrubs ($p = 0.0002$) around nests than were typical of plots. Chestnut-sided warbler nests had marginally fewer herbaceous stems ($n = 30$, $p = 0.08$) and significantly more *Rubus* ($p < 0.0001$). Yellow warbler nests also had more *Rubus* ($n = 21$, $p = 0.004$), as well as significantly fewer ferns ($p = 0.03$). Common yellowthroats (*Geothlypis trichas*) had more herbaceous stems ($n = 25$, $p = 0.003$) and *Rubus* ($p = 0.005$), and marginally fewer shrubs ($p = 0.10$) around nests. Song sparrow nests had significantly more *Rubus* around nests ($n = 49$, $p = 0.05$), and marginally more herbaceous stems ($p = 0.09$).

Nest success

In the two years, we found a total of 335 nests. Most species did not nest more successfully on either line, and all species together across the two years had better than half of nests fledge young. Both gray catbirds and yellow warblers, however, nested more successfully on the Volney-Marcy line – catbirds marginally so ($p = 0.06$), and warblers significantly so ($p = 0.02$).

In the artificial nest study, one plot had nearly all nests fail on both lines with only 5 % surviving the length of the experiment in either plot. In the other two plots, nests were notably more successful on the Volney-Marcy line (85% vs. 60% and 90% vs. 30%).

DISCUSSION

As Marshall et al. (2002) reported, the Fitzpatrick-Edic line has more shrubs and fewer herbaceous stems than the adjacent Volney-Marcy. This did not change significantly after the selective herbicide treatment was applied to the former sites after the 1999 breeding season. The vegetation differences could be the result of the mechanical treatments used for a decade on the Fitzpatrick-Edic line. On the other hand, the simple disparity in time since clearing may have given shrubs more time to establish themselves.

Regardless of the cause, the shrub densities are different on the two lines. The bird densities are also different. The bird species that are more abundant on the line with more shrubs are all species of shrub land habitat (Ehrlich et al., 1988). Several of these species also nested at sites with higher shrub or *Rubus* densities than were generally available. Marshall et al. (2002) concluded that any vegetation management that promoted shrubs should promote shrub land bird populations. Our species-specific observations of nest site selection seem to confirm that contention.

Densities, however, can be misleading (Vickery et al., 1992). Only by looking at nest success can we truly evaluate the value of rights-of-way as a shrub land bird reserve. Marshall et al. (2002) as well as Bramble et al. (1994) could not find significant differences between different vegetation management strategies and nesting success. We, on the other hand, found that some species had higher success on the Volney-Marcy line, where there is less shrub cover. We did not, however, detect any differences between the vegetation at successful and failed nests (Marshall, unpublished data). This suggests that the scale of our vegetation analysis may be inappropriate for detecting important factors affecting nest success in the right-of-way.

The artificial nest experiment certainly points to an interpretation of the differences in nest success on the two lines. Many of the nests on the Volney-Marcy were placed in the open with barely any cover to conceal them. Nests on the Fitzpatrick-Edic line, on the other hand, were usually under shrub cover or in stands of small trees. We expected the nests under cover to be far less likely to be depredated than nests sitting in the open. Our results were the exact opposite of our expectations.

Marshall et al. (2002) reported that most of the nest predators in the right-of-way are small mammals, particularly mice (*Peromyscus* spp.) and chipmunks (*Tamias striatus*). These predators, however, certainly have many predators of their own in the right-of-way. Such predators might include, but are not limited to, red-tailed hawks (*Buteo jamaicensis*), gray foxes (*Urocyon cinereoargenteus*), and coyotes (*Canis latrans*). Nest predators therefore likely require some cover of their own to avoid being prey. All of this leads us to suspect that birds nesting in shrubs face a tradeoff in nest site selection. Nesting in shrubs or *Rubus* might provide some protection from predators, but the same shrubs may also provide cover for nest predators. Small, isolated clumps of bushes, such as are common on the less shrubby Volney-Marcy line may provide better overall predator protection than the much more continuous cover on the Fitzpatrick-Edic line.

We do not have the data to sufficiently test these assertions. It does, however, suggest some potential avenues of investigation and some management recommendations. For research, we would investigate different shrub densities and different distributions of shrub cover to determine the shrub cover providing the most productive avian habitat. For recommendations, we would suggest that 100% shrub cover may not be as beneficial as our territory and nest density data might suggest. Various strategies, such as a wire-zone, border-zone approach (Niering and Goodwin, 1974), might provide a more beneficial shrub density. We are not suggesting that shrubs are not important to shrub land birds. Our results clearly show that the shrub land bird community thrives in shrub habitat. What we are suggesting is that research is needed to determine the optimal level of shrub cover for productive shrub land bird habitat.

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REFERENCES

Askins, R.A. 1994. Open corridors in a heavily forested landscape: impacts on shrub land and forest-interior species. Wildlife Society Bulletin, 22: 339–347.

Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1994. Nesting of breeding birds on an electric utility right-of-way. Journal of Arboriculture, 20: 124–129.

Confer, J.L. 2002. Management, vegetative structure and shrub land birds of rights-of-way. Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier, Amsterdam.

Ehrlich, P.R., D.S. Dobkins, and D. Wheye. 1988. The birder's handbook. Simon and Schuster, New York.

Finch, K.E. and S.D. Shupe. 1997. Nearly two decades of integrated vegetation management on electric transmission rights-of-way. Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier, Oxford.

International Bird Census Committee. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes, 24: 723–726.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk, 96: 651–661.

Marshall, J.S. and L.W. VanDruff. 2002. Impact of selective herbicide right-of-way vegetation treatment on birds. Environmental Management, 30 (6): 801–806.

Marshall, J.S., L.W. VanDruff, S. Shupe, and E. Neuhauser. 2002. Effects of powerline right-of-way vegetation management on avian communities. Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier, Amsterdam.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin, 87: 456–466.

Niering, W.A. and R.H. Goodwin. 1974. Creation of relatively stable shrub lands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology, 55: 784–795.

Porter, W.F. and J.A. Hill. 1998. Regional trends of biological resources – Northeast. Status and Trends of the Nation's Resources. Vol. 1. USGS, Reston, Virginia.

Sauer, J.R. and B.K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. Journal of Wildlife Management, 53: 137–142.

Vickery, P.D., M.L. Hunter, and J.V. Wells. 1992. Is density an indicator of breeding success? Auk, 109: 706–710.

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PacifiCorp's Bird Management Program: Integrating Reactive, Proactive, and Preventative Measures to Reduce Avian Mortality on Power Lines

Sherry Liguori and Jim Burruss

For several decades, utilities and wildlife resource agencies have worked together to reduce detrimental impacts to birds while providing reliable electricity. The Avian Protection Plan (APP) Guidelines recently developed by the Avian Power Line Interaction Committee (APLIC) and U.S. Fish and Wildlife Service (FWS) represent another accomplishment in this ongoing partnership. These guidelines provide guidance and resources for utilities that wish to develop or enhance a program to benefit avian species and reduce outages associated with birds. In this paper, each of the APP Guidelines is discussed and specific examples are provided from PacifiCorp's Bird Management Program.

Keywords: Avian Protection Plan, APLIC, electrocution reduction, ROW

BACKGROUND

Since the 1970's the utility industry has worked with wildlife resource agencies and organizations to identify causes of avian mortality on power lines and develop solutions to minimize avian electrocution and collision risk. The Avian Power Line Interaction Committee (APLIC) was formed in 1989 to address collision issues of cranes with power lines. Comprised of utility biologists and US Fish and Wildlife Service (FWS) members, APLIC has continued to address electrocution, collision, and nest issues. In 2003–2004, APLIC and FWS developed Avian Protection Plan (APP) Guidelines for utilities. These voluntary guidelines are intended to allow utilities to tailor an APP that will best fit their utility needs while furthering the conservation of avian species and improving reliability and customer service. They are intended to be used in conjunction with APLIC's *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996* and *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994*, which both contain more detail on construction design standards and line siting recommendations. In addition, utilities are encouraged to work in partnership with federal and state wildlife resource agencies when developing their APP. A utility that develops an APP following these guidelines and that addresses their specific avian issues can benefit through regulatory compliance, reliability improvements, and positive recognition from regulators and customers. Additional information on the APP Guidelines can be obtained at www.aplic.org.

PacifiCorp, a utility that operates in six states of the western U.S. (Utah, Wyoming, Idaho, Oregon, Washington, California), has had a Bird Management Program in place since the mid-1980's. Because of its large, multi-state service territory, PacifiCorp has faced numerous challenges in developing, applying, documenting, and monitoring avian protection measures company-wide. To provide a standard of avian protection that could be applied throughout the company, PacifiCorp developed its Bird Management Program. The elements detailed in the APP guidelines are practiced by PacifiCorp's program and have been used as examples in the development of the APP guidelines.

This paper details the specific components of the APP Guidelines developed by APLIC and FWS. In addition, specific examples of how PacifiCorp's Bird

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Management Program addresses these guidelines are presented.

WHAT IS AN AVIAN PROTECTION PLAN?

An Avian Protection Plan (APP) is a utility-specific document that delineates a program designed to protect and conserve migratory birds by reducing the risks that result from avian interactions with electric utility facilities. Although each utility's APP will be different, the overall goal of any APP should be to reduce avian mortality and bird related outages. The APP Guidelines provide principals and examples to aid utilities in their development of an APP. The following 12 components should be considered for inclusion in a utility APP:

1. Corporate policy
2. Training
3. Permit compliance
4. Construction design standards
5. Nest management
6. Avian reporting system
7. Risk assessment methodology
8. Mortality reduction measures
9. Avian enhancement options
10. Quality control
11. Public awareness
12. Key resources for troubleshooting

Corporate policy

An APP typically includes a statement of company policy confirming the company's commitment to work cooperatively towards avian protection. This may include a commitment by the company to balance its goal of providing reliable electrical service in a cost-effective manner with the regulatory requirements protecting avian species, as well as the need to obtain and comply with all necessary permits, monitor incidents of avian mortality, and make reasonable efforts to construct and alter infrastructure to reduce the incidence of avian mortality.

PacifiCorp's Bird Management Program is guided by the company's Bird Management Policy. This policy is intended to ensure compliance with legal requirements, while improving system reliability. Management and employees are responsible for managing bird interactions with power lines and are committed to reducing the detrimental effects of these interactions. This policy is distributed to all field offices throughout the company and posted on PacifiCorp's internal website. To fulfill its commitment, the policy states that the company will abide by the following practices:

- Implement and comply with PacifiCorp's Bird Management Program;
- Ensure that PacifiCorp's actions comply with applicable laws, regulations, permits, and Bird Management Program procedures;
- Document bird mortalities and problem nests;
- Provide information, resources, and training to improve employee's knowledge and awareness;
- Construct all new or rebuilt lines in rural areas to company raptor-safe standards;
- Conduct remedial actions at power poles where a protected bird has died;
- Participate with public and private organizations in programs and research to reduce detrimental effects of bird interactions with power lines.

Training

All appropriate utility personnel, including managers, supervisors, field, engineering, dispatch, and design personnel, should be properly trained in avian issues. This training should encompass the reasons, need, and method by which employees should report an avian mortality, follow nest management protocols, dispose of carcasses, and comply with applicable regulations, including the consequences of non-compliance. Supplemental training also may be appropriate where there are material changes in regulations, permit conditions, or internal policies.

PacifiCorp provides its employees with numerous resources to identify roles and responsibilities, detail standard practices, and ensure compliance with its policies and procedures. Training is conducted with field personnel annually or more frequently if necessary. This training includes a presentation detailing applicable regulations, protected bird species, raptor-safe construction standards, and reporting procedures. In addition, a hands-on overview of avian protection devices is conducted with discussion and feedback from the field. All field offices have a copy of PacifiCorp's Bird Program Guidelines, which provide detailed policy and procedures, construction standards, and other information/resources. These guidelines are also accessible to all employees via company intranet. Specific, quick reference training tools are also provided. Examples include laminated sheets on procedures for bird mortalities and problem nests; an identification sheet of protected vs. non-protected bird species; and a binder of the most commonly used raptor protection standards and equipment. Additional training tools are developed as needed or requested by the field. Training is also provided to clerks, dispatchers, estimators, and others who are responsible for implementing the company's Bird Management Policy.

Permit compliance

An APP typically identifies the process under which a company obtains and complies with all necessary permits related to avian issues. Particular attention should be given to specific activities that can require Special Purpose Permits including, but not limited to, nest relocation, temporary possession, depredation, salvage/disposal, and scientific collection. In addition to permits, a utility should be aware of the regulations applicable to migratory bird conservation (Migratory

Bird Treaty Act, Bald and Golden Eagle Protection Act, Endangered Species Act). A utility should also work with FWS and other regulatory agencies to obtain necessary permits and identify ways to minimize negative impacts to migratory birds.

PacifiCorp has had Memoranda of Understanding (MOU) in place with FWS and each state wildlife resource agency in its service area for over a decade. These MOUs have established a framework for cooperative efforts among PacifiCorp and agencies. PacifiCorp reports annually to FWS the number and location of birds killed on its lines. In addition, eagles are reported immediately to FWS, who retrieves the bird for donation to the National Eagle Repository. PacifiCorp possesses a Special Purpose Permit that allows the temporary possession of other migratory birds for burial. In addition, special permits are obtained, as needed, for active nest relocation.

Construction design standards

Avian interactions should be considered in the design and installation of new facilities, as well as the operation and maintenance of existing facilities. For those reasons, inclusion of accepted construction standards for both new and retrofit techniques also should be included in an APP. Companies can either rely upon existing construction configurations recommended by APLIC (see *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996* and *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994*) or may choose to instead develop their own internal construction standards that meet or exceed these guidelines. These standards should be used in areas where new construction should be avian-safe, as well as where existing infrastructure should be retrofitted to provide avian safety.

PacifiCorp's raptor-safe construction design standards are available to employees via company intranet or through a quick reference guide to the most common configurations. These standards meet or exceed those recommended by APLIC and provide a minimum clearance of 60-inches between phases or phases and grounds. To achieve this spacing on a three-phase line, either a 10-foot crossarm or a lowered 8-foot arm is used. Insulator covers or perch guards may be applied to existing structures where they would provide effective avian protection. Exposed equipment, particularly transformers, are covered to prevent birds from making contact with energized wires or other equipment. New avian protection products are tested in the field to determine their effectiveness, ease of installation, and durability.

Nest management

An APP may include procedures for nest management on utility structures. These procedures should be explained to company employees during training to ensure uniform treatment of avian nest issues among personnel. Appropriate permits should be obtained for relocating nests or removing nests due to safety or fire risks.

PacifiCorp documents problem nests on its facilities and takes action when there is a risk of fire, safety to line crews or others, or electrocution of nesting birds. Preventative action, prior to egg-laying, is recommended. Osprey and Common Ravens are the species that most commonly nest on PacifiCorp's facilities. Problem nests are typically relocated to a nest platform on a non-energized pole that is taller and set nearby the existing nest.

Avian reporting system

Although reporting of avian mortalities may be required as a condition of federal or state permits, a utility may also choose to voluntarily monitor relevant avian interactions, including mortalities, through the development of an internal reporting system. An APP should provide for the development of such a reporting system, which can help a company pinpoint areas of concern by tracking both the specific locations where mortalities may be occurring, as well as the extent of such mortalities. Data collected by company personnel can be limited to avian mortalities or injuries, or could be expanded to include historical tracking of avian nest problems, particularly problematic poles or line configurations, as well as remedial actions taken. All data should be regularly entered into a searchable database compatible for use in additional analysis (see Risk Assessment Methodology below). Bird Mortality Tracking System (BMTS) software developed by APLIC is available for free upon request at http://www.aplic.org.

PacifiCorp employs a BMTS program similar to that offered by APLIC. Through this program, bird mortalities and problem nests are documented. BMTS is accessible to employees online and field forms may also be kept in company vehicles. The program is used to generate annual reports on mortalities and nest actions, track the location and extent of avian mortality or nest issues, and document corrective actions and associated costs.

Risk assessment methodology

A utility can have the greatest impact on reducing avian mortality by focusing its efforts in a cost-effective manner on the areas that pose the greatest risk to migratory birds. Therefore, as a general matter, an APP should include a method for evaluating the risks posed to migratory birds in a manner that identifies areas and issues of particular concern. A risk assessment will often begin with an assessment of available data addressing areas of high avian use, avian mortality, nesting problems, established flyways, adjacent wetlands, prey populations, perch availability, and other factors that can increase avian interactions with utility facilities. The avian reporting system discussed in the previous section is an integral component of this risk assessment, as well as the use of avian experts, birders, and biologists who can provide additional information on avian distribution. An APP also may provide for the development of models that will enable a company to utilize biological and electrical design information to prioritize poles most in need of repair, as well as research on the varied causes of avian mortality and the benefits of utility structures to avian species.

The number of overhead facilities throughout PacifiCorp's large geographic service area creates a challenge when attempting to identify and retrofit existing structures that pose an avian electrocution risk. Consequently, PacifiCorp has developed a process to identify areas of increased electrocution risk so that limited resources can be applied where they are most effective. In 2001, pilot surveys were conducted in portions of PacifiCorp's Utah service area to develop and apply a method to assess avian electrocution risk. This method, developed with the input of biologists from PacifiCorp, HawkWatch International, UT Division of Wildlife Resources, and US Fish and Wildlife Service (Law Enforcement and Ecological Services offices), combined field data with existing GIS coverages to geographically identify and rank electrocution risk. The same risk assessment was conducted in 2002 for the remainder of PacifiCorp's service territory in rural Utah as well as southwestern Wyoming. In 2004, risk assessments have been conducted in portions of PacifiCorp's service territory in northern California. The results of these risk assessments are used to develop remedial action plans that address poles that are not known to have caused an avian electrocution, but possess specific criteria that make them pose an elevated electrocution risk.

Mortality reduction measures

A risk assessment or similar evaluation can help a utility set priorities for reducing avian mortality and associated outages. After completing a risk assessment, a company can focus its efforts on areas of concern, ensure that the activities taken by the utility are not out of proportion to the risks encountered by migratory birds, and then determine whether an avian mortality reduction plan needs to be implemented in certain areas. An APP could implement this approach by developing such a risk reduction plan, utilizing risk assessment results to direct where system monitoring should occur, where retrofit efforts should be focused, and where new construction warrants special attention to raptor and other bird issues. If a utility finds that implementation of such avian protection measures is appropriate, it also may choose to develop a schedule for implementation.

PacifiCorp applies a three part approach to reducing avian mortality; this approach includes preventative, reactive, and proactive measures. Examples of a preventative approach include constructing all new lines or rebuilds in rural areas to raptor-safe standards, conducting remedial actions at poles during outage calls, ensuring compliance with applicable laws, regulations, and permits, and considering avian issues (i.e. collision prevention, critical habitat protection) in the siting of new lines. Reactive measures include documenting avian mortalities and problem nests and conducting remedial actions at poles where protected bird species are killed. PacifiCorp's proactive approach includes conducting risk assessments and developing associated remedial action plans, providing employee resources and training, and monitoring areas where there is a history of electrocutions and remedial actions.

Avian enhancement options

In addition to taking steps to reduce mortality risk to avian species, an APP also may include opportunities for a utility to enhance avian populations or habitat, including developing nesting platforms, managing habitats to attract migratory birds, or working cooperatively with agencies or organizations in such efforts. Where feasible, such proactive development of new ideas and methods to protect migratory birds should be encouraged and explored.

PacifiCorp seeks opportunities to partner with agencies, conservation and education organizations, scout groups, and others to benefit migratory birds and increase public awareness of the importance of avian and habitat conservation. These partnerships have resulted in on-the-ground accomplishments such as the installation of nesting platforms and boxes, habitat enhancement and riparian restoration projects, and improvement of wildlife viewing and outdoor recreational opportunities. Such projects present a win-win opportunity for the utility, the public, and the resource.

Quality control

An APP also may include a mechanism to review existing practices, ensuring quality control. For instance, a utility may conduct an independent assessment of its avian reporting system to ensure its effectiveness, or invest in research on the effectiveness of different techniques and technologies used to prevent collisions, electrocutions and problem nests.

PacifiCorp implements measures to assess and continually improve its procedures, assessments, and actions. Feedback is obtained from field personnel on the effectiveness, ease of installation, and durability of different avian protection products. Remedial actions are spot-checked in the field to ensure that appropriate devices are installed correctly. Follow-up surveys are conducted to evaluate the effectiveness of risk assessments and remedial actions. Processes for documenting bird mortalities, bird-related outage, and remedial actions are refined as needed. Training for appropriate personnel is conducted annually or more frequently if warranted due to changes in procedures or availability of new avian protection devices.

Public awareness

An APP generally should include a method to educate the public about the company's avian protection program, as well as its successes in avian protection. Efforts made by a utility on behalf of avian conservation provide an excellent opportunity to inform the public of the company's work and its benefits to avian populations or habitats.

As a "green" company, PacifiCorp takes its commitments towards protecting avian species and reducing its overall environmental impacts very seriously. Avian enhancement efforts and proactive remedial actions allow PacifiCorp to showcase its commitment to protecting migratory birds. In addition to working directly with scout groups and others, PacifiCorp supports organizations dedicated to environmental education and wildlife and habitat conservation.

Key resources for troubleshooting

An APP should identify key resources to address avian protection issues including, for example, a list of experts who may be called upon to aid in resolving avian issues. Engineers may find that internal personnel such as environmental specialists can aid in developing creative solutions to resolve avian interaction problems, and external organizations like APLIC can also serve as helpful resources by providing guidance, workshops, materials, and contacts. Many sources can provide insights into raptor and other bird behavior which can influence how and when avian protection should be best utilized, and an APP that connects these experts with utility decision-makers may further reduce the risk of avian incidents, thus improving system reliability.

Because many individuals play a role in upholding PacifiCorp's Bird Management Policy, the company relies on various internal management units in its day-to-day operations. In addition, numerous external resources aid the company through collaborative on-the-ground efforts. The support of managers and field crews within the company is critical to ensure that bird mortalities are documented and appropriate actions are taken in a timely manner. Likewise, support from state and federal wildlife resource agencies is imperative to a successful program. Partnerships with agency biologists and other experts help PacifiCorp to improve its avian conservation efforts and identify areas of biological significance.

IMPLEMENTING AN AVIAN PROTECTION PLAN

The APP Guidelines developed by FWS and APLIC were intended to provide a framework for a utility to customize its own APP with input from local wildlife resource agencies. A utility should select the APP components applicable to its circumstances to meet its individual needs. The examples provided by PacifiCorp's program demonstrate how one utility has addressed each of the APP components; the efforts of other utilities will likely vary due to differences in operating procedures, geographic extent of territory, local avian species of concern, funding resources, etc. Regardless of how an APP is implemented, it demonstrates the accomplishments made by the utility industry and wildlife resource agencies towards the conservation of migratory birds and the reliable delivery of electricity.

REFERENCES

Avian Power Line Interaction Committee (APLIC). 1996. Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996. Edison Electric Institute and the Raptor Research Foundation. Washington, D.C.

Avian Power Line Interaction Committee (APLIC). 1994. Mitigating Bird Collisions with Power Lines: The State of the Art in 1994. Edison Electric Institute. Washington, D.C.

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Minimizing Bird Collisions: What Works for the Birds and What Works for the Utility?

John M. Bridges, Theodore R. Anderson, Dirk Shulund, Linda Spiegel, and Tim Chervick

Bird collisions with overhead wires have been reported in the United States at least since 1876. A number of solutions have been tried all with varying degrees of success. Raptor silhouettes, different color marker balls, "bird diverters," "flappers" and various other devices to warn birds all work to some degree. However, depending on the target species and the object being marked, if you use the wrong type or color of device it may not be effective, could result in a maintenance problem, or may even cause lines to go down. To date, there is very little published empirical data on which device works for which species or group of species. Anecdotal information suggests that some things do not work as well for some bird species as they do for others. This paper will discuss the mitigative measures found in the literature and provide a brief evaluation of their effectiveness and some of the problems they may create. It will also discuss some of the on-going research, including the effects of motion and light, where information is available. Evaluation of marking devices will be based on existing literature, the experience of line crews and personal experience.

Keywords: Bird collisions, power lines, line marking devices, bird diverters, flappers, right-of-way

INTRODUCTION

Bird collisions with overhead wires are a global issue. They have been noted as a cause of mortality in the United States (U.S.) at least since 1876 (Coues, 1876). Avery (1978) summarized the issue of bird collisions with transmission lines for the U.S. Fish and Wildlife Service. Faanes (1987) examined bird flight behavior in the presence of transmission lines in the northern Great Plains of the U.S.; Telfer et al. (1987) discussed bird collisions in Hawaii; Ledger et al. (1993) discussed collisions in South Africa; Bevanger (1993) compared ptarmigan (*Lagopus lagopus*) collision mortality with hunting mortality in Norway; Boyd (1961) reported on collisions of banded waterfowl in Great Britain; Alonso et al. (1993) and Roig and Navazo (1997) describe collisions in Spain; Hess (1999) is working on the problem in Australia; and De La Zerda and Rosselli (2002) describe some of the problems in Columbia. Additionally, there are numerous articles dealing with bird collisions in both peer-reviewed journals and the popular press (see California Energy Commission 1995 and 2002). Bird mortality due to collisions with a single transmission line, generally is not considered not biologically significant (Faanes, 1987; Hugie et al., 1993). As Brown (1993) pointed out, however, cumulatively, bird deaths due to collisions, combined with other forms of mortality (e.g. habitat loss and fragmentation), can result in significant effects to a population. Additionally, some lines, such as those crossing wildlife refuges, may have more significant impacts than currently understood due to inadequate survey efforts.

Birds collide with transmission lines because of hampered visibility or because they are occupied by something else such as courtship, hunting, or escape. Decreased visibility due to inclement weather can result in a higher incidence of collisions (Krapu, 1974). Incidence of collisions tend to increase during spring mating season and again during the late summer and fall when young of the year are learning the intricate maneuvers of flight (Hugie et al., 1993). Panic flushes

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also result in collisions, particularly of flocking birds (e.g. waterfowl, wading birds, or shorebirds) (Krapu, 1974; Schroeder, 1977). Some species are more susceptible to collisions than other species. Crowder and Rhodes (2002) related this in part to the ratio of wing aspect to wing loading.

MINIMIZING COLLISIONS

The Avian Power Line Interaction Committee (APLIC) has summarized the methods used to reduce collisions (APLIC, 1994). These include careful location of the line when originally routed. If the line is already in place, a two-year four-season study is recommended to determine if a collision problem exists, what the aerial extent of the problem is, what species are involved and where on the line the collisions occur. Based on the results of the study, the problem may be minimized by removing the overhead ground wire, if that is where the collisions occur, and when it is appropriate, and/or marking the lines with some type of device to make them more visible. Marking devices include aviation marker balls, spiral vibration dampers, air flow spoilers, bird flight diverters of various designs and dimension, and several devices that have movement, such as swinging plates or flappers.

Obviously the best way to minimize bird collisions with transmission and distribution lines is avoidance of the situation. That is, in the initial planning stages of a new line, stay away from areas where birds tend to congregate. These include feeding and loafing areas, the communication flyways between them, as well as migratory staging areas, particularly wetlands and rivers. Unfortunately, avoidance is not always practical due to engineering, environmental or economical constraints. Although it is generally impractical if the line is already in place, however, in some cases problem lines have been relocated.

In the last 20 years, increased efforts have gone into finding the best methods of dealing with existing lines that are known to have bird collisions. Two international workshops on the subject of birds and the electric utility industry have been held in the United States since the early 1990's. Several others have been held in South Africa, the Middle East, and Europe. To understand how to make an object more visible to birds, we must first understand how a bird views its environment and how it reacts to that visual input (see Cook, 2001). Obviously most birds are dependent on vision for mating and feeding. One has but to look at the coloration of breeding plumage or the hunting techniques of raptors, vermivores or carrion feeders.

According to Faanes (1987), most bird collisions in his study occurred with the overhead ground wire when the birds veered up to avoid the conductors. Beaulaurier et al. (1984) found that removing the overhead groundwire or shield wire was very effective in the Pacific Northwest. In areas that experience a lot of lightning, however, this would leave major transmission systems exposed to numerous outages. Additionally, there are studies that infer the ground wire is not the cause for collision in every instance (Anderson, 1978; Krapu, 1974). Meyer (1978) found marking the overhead groundwire works with varying degrees of success. APLIC (1994) lists the effectiveness of various line marking devices (i.e., 12-inch marker balls, spiral vibration dampers and bird flight diverters) with a range of 40 to 89 percent, depending on device and spacing on the lines. Brown and Drewien (1995) studied the effectiveness of different marking devices (i.e., swinging plates and spiral vibration dampers) and they found the marking devices resulted in changed flight behaviors and reduced collisions (by 63 and 61 percent, respectively). They reported the effectiveness, however, varied by device, season and species. The swinging plate had some initial problems with the clamp. The clamp moved slightly in strong winds and began to wear on the wires. Crowder (2000) reviewed the relative effectiveness of bird flight diverters and swan flight diverters. He reported that bright colored (yellow) bird flight diverters were better at reducing collisions than gray (76 to 58 percent) but the gray swan flight diverters were more effective than yellow (44 to 25 percent). Roig and Navazo (1997) found that "white spirals" spaced every 10 meters on the overhead ground wire were effective. Where overhead ground wires were not present, they attached a 35 centimeter long, black, neoprene strip to the conductor and that worked almost as well. Koops and de Jong (1981) studied the effectiveness of "bird flight diverters" in Denmark and found that, depending on the spacing of the diverters on the wires, they reduced bird collisions by 57 to 89 percent. Telfer (1999) found that bird flight diverters had little effect on shearwater (*Puffinus* sp.) collisions, but yellow aviation marker balls with 8-inch black dots worked quite well. Beaulaurier et al. (1984) also used orange aviation marker balls, fishing floats and yellow streamers, all with some success. Bird flappers, a device that attaches to either the groundwire or conductor, have been suggested by Miller (1993) and Ledger et al. (1993). Van Rooyen (2000) placed flappers on lines in South Africa and found them to reduce bird collisions. Janss et al. (1999) found the use of raptor models (i.e. eagles *Aquila* sp. and *Accipiters*) mounted on transmission line structures, to reduce collisions. They found that the models had no effect on collisions or the potential for collisions.

More recent studies and reports on bird vision have led to the development of devices that work in the wavelength that birds use and have motion that catches bird's attention. Birds use motion to detect and hunt for food, and avoid predators. Some birds have the ability to define and distinguish patterns and objects using only motion information (Dittrich and Lea, 2001). Hawks, penguins and insectivorous birds are strictly dependent on motion cues for detecting prey at great distances. Many bird species have the ability to see at two peak wavelengths of light (Springsteen, 2003). One peak wavelength, 560 nanometers (nm) or yellow color, is shared with humans in the visible light range. The other peak wavelength of light, 360 nm wavelength, which is in the A-band of ultra-violet light, is found in sunlight and is invisible to humans. McGraw (2004) states that color signaling by birds play an important function in locating and acquiring food, attracting mates, mediating aggressive behavior, and avoiding predation. The complex retina and sensitive vision of birds surpass those of most animals (Hart, 2001). Bird feathers reflect light within the multilayered arrangement of feather barbs and barbules, causing iridescent effect in some bird feathers. This iridescent color may function in important signaling within different bird species (McGraw, 2004). According to Husband and Shimizu (2001), birds appear to have excellent color vision which may be based on their having four or five photo pigments, compared to three in primates. This may explain the success Telfer (1999) had with marking lines with yellow marker balls that he painted with large black spots. As Janss et al. (1999) found, however, when using raptor models to haze birds, not all birds interpret a warning device as a warning. Smaller birds tended to harass the models.

At this time there are several studies underway to test the efficacy of the devices to warn birds of objects in the air. Red Electrica de Espana is testing devices on some of its lines (Roig, 2004). Eskom is also testing the "flapper" on flamingos and blue crane collisions in South Africa (Van Rooyen and Smallie, 2003). They found the flappers reduced flamingo collisions by 82 percent and blue crane collisions by 84 percent. There is also a consortium of partners developing the technology to test line marking devices and monitor bird activity for projects in North Dakota and California (California Energy Commission, 2003). The Technical Advisory Group for this study includes three agencies in the U.S. Department of Interior, two agencies in the U.S. Department of Energy, two agencies in the U.S. Department of Agriculture, one agency in the U.S. Department of Commerce and one in the Department of Defense. There are electric utilities, environmental organizations and interested individuals from five continents also participating. Several state agencies, along with the Electric Power Research Institute and the Avian Power Line Interaction Committee are also involved.

CONCLUSIONS

With all of these techniques, it is important to remember that the purpose of the wire is to aid in the reliable delivery of electricity. The amount of lightning activity has to be considered before removing the overhead groundwire. Aviation marker balls and anything else placed on a line, tend to accumulate ice and snow in northern latitudes and at higher altitudes. As one might expect, the bigger the device the more weight will be added to the line. Ice- and wind-loading potential need to be evaluated before attaching anything to either the conductors or the groundwires. Design engineers can answer questions on the ability of the line to bear up under the additional weight of the marking device, especially with the added weight of ice and/or snow. The same is true for wind loading. Aeolian wind dampers are used on distribution and sub-transmission lines to minimize the adverse actions of wind (i.e., galloping or slapping). These may be useless if a device with a large surface area is attached to the line or shield wire. Additionally, the clamp that attaches the device to the conductor or the shield wire, whether it is an aviation marker ball, spiral bird-flight diverter or flapper may also wear on the wire it is attached to, resulting in failure of the wire. Another engineering issue associated with marking devices is corona discharge, which can result in audio noise, radio or television interference, create safety issues, or impede the flow of electricity. The California Energy Commission and the Western Area Power Administration are currently funding research to determine the corona discharge of several marking devices at various voltages. And finally, whatever mitigation is applied needs to be reviewed periodically to ascertain its effectiveness (no one device will work for every situation) and determine the need for repair and/or replacement. If that need arises too frequently, the maintenance of the device and of the line may become too costly, and these costs are passed on to the users.

REFERENCES

Alonso, J.C., J.A. Alanso, R. Munoz-Pulido, J. Roig, V. Navazo, and J. Arevalo. 1993. Senalizacion de lineosdealta tension para la proteccion de la avifauna. Red Electrica de Espana, S.A. 58 p.

Anderson, W.L. 1978. Waterfowl collisions with power lines at a coal-fired power plant. Wildl. Soc. Bull., 6: 77–83.

Avery, M.T. (ed). 1978. Impacts of transmission lines on birds in flight. U.S.D.I. Fish and Wildlife Service. FWS/OBS-78/48. 151 p.

Avian Power Line Intreraction Committee (APLIC). 1994. Mitigating bird collisions with power lines: the state of the art in 1994. Edison Electric Institute, Washington, DC 103 p.

Beaulaurier, D.L., B.W. James, P.A. Jackson, J.R. Myers, and J.M. Lee, Jr. 1984. Mitigating the incidence of bird collisions with transmission lines. P. 539–550. In A.F. Crabtree (ed). Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State Univ., MS. 689 p.

Bevanger, K. 1993. Hunting mortality versus wire-strike mortality of willow grouse (*Lagopus lagopus*) in an upland area of southern Norway. P11-1–11-10. In APLIC. Proceedings: Avian Interactions with Utility Structures International Workshop. EPRI, TR-103268 (Project 3041), Palo Alto, CA.

Boyd, H. 1961. Reported casualties to ringed ducks in the spring and summer. Wildfowl Trust, 12: 144–146.

Brown, W.M. 1993. Avian collisions with utility structures: biological perspectives. P12-1–12-13. In APLIC. Proceedings: Avian Interactions with Utility Structures International Workshop. EPRI, TR-103268 (Project 3041), Palo Alto, CA.

Brown, W.M. and R.C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. Wildlife Soc. Bull., 23: 217–227.

California Energy Commission. 1995. Avian collision and electrocution: an annotated bibliography. Sacramento, CA. P700-95-001.

California Energy Commission. 2002. A roadmap for PIER research on avian collisions with powerlines in California. Sacramento, CA. P500-02-071F.

California Energy Commission. 2003. Bird Strike Indicator/Bird Activity Monitor and Field Assessment of Avian Fatalities. Sacramento, CA. 500-03-107F.

Cook, R.G. 2001. Avian visual congintion. [On-line.] Available: www.pigeon.psy.tufts.edu/avc/ Downloaded 6/12/2004.

Coues, E. 1876. The destruction of birds by telegraph wire. American Naturalist, 10(12): 734–736.

Crowder, M.R. 2000. Assessment of devices designed to lower the incidence of avian power line strikes. Master of Science Thesis, Purdue University, East LaFayette, IN. 91 p.

Crowder, M.R. and O.E. Rhodes, Jr. 2002. Relationships between wing morphology and behavioral responses to unmarked power transmission lines. P. 403–410. In J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds). The Seventh International Symposium on Environmnetal Concerns in Rights-of-Way Management. 9–13 September, 2000. Calgary. AB, Canada. Elsevier Publ. Co. Oxford, UK. 955 p.

De La Zerda, S. and L. Rosselli. 2002. Mitigating collision of birds against transmission lines in wetland areas in Columbia by marking the ground wire with bird flight diverters (BFD). P. 395–402. In J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds). The Seventh International Symposium on Environmnetal Concerns in Rights-of-Way Management. 9–13 September, 2000. Calgary. AB, Canada. Elsevier Publ. Co. Oxford, UK. 955 p.

Dittrich, W.H. and S.E.G. Lea. 2001. Motion discrimination and recognition. In R.G. Cook (ed). Avian visual cognition. [On-line.] Available: www.pigeon.psy.tufts.edu/avc/dittrich/ Downloaded 6/12/2004.

Faanes, C.A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. USDI, Fish and Wildlife Service, Tech. Rep. No. 7. 24 p.

Hart, N.S. 2001. The visual ecology of avian photoreceptors. Prog. Ret. Eye Res., 20: 675–703.

Hess, J. 1999. Tasmania Hydro. Personal communication with J. Bridges.

Hugie, R.D., J.M. Bridges, B.S. Chanson, and M. Skougard. 1993. Results of a post-construction bird monitoring study on the Great Falls-Conrad 230-kV transmission line. P16-1–16-21. In APLIC. Proceedings: Avian Interactions with Utility Structures International Workshop. EPRI, TR-103268 (Project 3041), Palo Alto, CA.

Husband, S. and T. Shimizu. 2001. Evolution of the avian visual system. In R.G. Cook (ed). Avian visual cognition. [On-line.] Available: www.pigeon.psy.tufts.edu/avc/husband/ Downloaded 6/12/2004.

Janss, G.F.E., A. Sazo, and M. Ferrer. 1999. Use of raptor models to reduce avian collisions with powerlines. Journal of Raptor Research, 33: 154–159.

Koops, F.B.J. and J. de Jong. 1981. Vermindering van draadslachtoffers door markering van hoogspanningsleidengen in de omgeving van heereven. Overdruk uit:lektrotechniek, 60: 641–646. (Translation provided by Dulmison, Inc., Lawrenceville, GA.)

Krapu, G. 1974. Avian mortality from collisions with overhead lines in North Dakota. Prairie Naturalist, 6(1): 1–6.

Ledger, J.S., J.C.A. Hobbs, and T.V. Smith. 1993. Avian interactions with utility structures: South African experience. P4-1–4-11. In APLIC. Proceedings: Avian Interactions with Utility Structures International Workshop. EPRI, TR-103268 (Project 3041), Palo Alto, CA.

McGraw, K.J. 2004. Multiple UV reflectance peaks in the iridescent neck feathers of pigeons. Cornell University, Department of Neurobiology and Behavior, Ithaca, NY. Available: http://people.cornell.edu/pages/kjm22/ Downloaded 7/21/2004.

Meyer, J.R. 1978. Effects of transmission lines on bird flight behavior and collision mortality. USDOE Bonneville Power Admin. 200 p.

Miller, A.D. 1993. The engineering perspective of power line marking systems to reduce avian collisions. P13-1–13-14. In APLIC. Proceedings: Avian Interactions with Utility Structures International Workshop. EPRI, TR-103268 (Project 3041), Palo Alto, CA.

Roig, J. 2004. Head of Environmental Department, Red Electica de Espana. Personal communication with J. Bridges.

Roig, J. and V. Navazo. 1997. A five-year Spanish research project on bird electrocutions and collisions with electric lines. pp. 317–325. In J.R. Williams, J.W. Goodrich-Mahoney, Jan R. Wisniewski and J. Wisniewski (eds). The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier Science, Ltd. Oxford, UK. 511 p.

Schroeder, C. 1977. Geese hit power transmission line. North Dakota Outdoors, 40: 1.

Springsteen, A. 2003. Avian Technologies, Inc. Personal Communication with T. Chervick.

Telfer, T.C. 1999. Hawaii Department of Forestry and Wildlife. Personal communication with J. Bridges.

Telfer, T.C., J.L. Sincock, G.V. Byrd, and J.R. Reed. 1987. Attractions of Hawaiian birds to lights: conservation efforts and effects of moon phase. Wildlife Society Bulletin, 15: 406–413.

Van Rooyen, C. 2000. Eskom, South Africa. Personal communication with J. Bridges.

Van Rooyen, C. and J. Smallie. 2003. Mercury-Perseus 400-kV transmission line bird impact assessment study. Strategic Environmental Focus, Lynnwood Ridge, South Africa. 10 p.

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Bird Nesting Ecology on a Right-of-Way in Central Pennsylvania: Long-Term Effects of the Wire-Border Zone Method

Richard H. Yahner, Richard T. Yahner, Bradley D. Ross, and Russell J. Hutnik

We studied the long-term nesting ecology of birds on the State Game Lands (SGL) 33 Research and Demonstration Area, which is located along a 230-kV transmission right-of-way (ROW) of FirstEnergy (Penelec) in the Allegheny Mountain Region, Centre County, Pennsylvania, during 2002 and 2003. The objectives of this study were to compare nest abundance, success, and placement (1) in handcut versus herbicide-treated study sites (units) and (2) in wire versus border zones. In 2002 and 2003, 33 and 26 nests of 10 bird species were noted, principally those of species adapted to early successional habitats created by the wire-border zone method of vegetation maintenance on the ROW. Thirteen (39%) of 33 nests of all species combined fledged young in 2002 compared to 17 (65%) of 26 nests in 2003. Nesting success in 2003 on the SGL 33 ROW was typical of most studies of bird nesting success in a variety of habitats and was comparable to that recorded in 1991–92. Thirty-five (59%) of the 59 nests were in wire zones, whereas 24 (41%) nests were in border zones. The State Game Lands 33 Research and Demonstration Area provides nesting habitat for a variety of bird species. Because species dependent on early successional habitats are showing population declines, the maintenance of a ROW via the wire-border zone method is extremely valuable to the long-term conservation of these bird species.

Keywords: Birds, handcut vegetation, herbicides, nesting ecology, rights-of-way, vegetation management, wire-border zone method, ROW

The State Game Lands (SGL) 33 Research and Demonstration Project in Centre County, Pennsylvania, has been studied since 1953, making this 51-year-old project the longest continuous project documenting the effects of mechanical and herbicidal maintenance on flora and fauna along an electric transmission right-of-way (ROW) (Vistas, 2003; Yahner et al., 2002a). Transmission ROW are linear corridors that often traverse contiguous forests, thereby making these ROW extremely valuable for bird species requiring early successional habitats (Bramble et al., 1992a; 1994; Yahner et al., 2002a; 2003a). For instance, most nests found on the SGL 33 ROW in 1991–1992 were those of early successional species, including field sparrow (*Spizella pusilla*), gray catbird (*Dumetella carolinensis*), eastern towhee (*Pipilo erythrophthalmus*), and common yellowthroat (*Geothlypis trichas*), and indigo bunting (*Passerina cyanea*) (Bramble et al., 1994).

Early successional habitat has become less common in the forests of the eastern United States in recent decades (Trani et al., 2001), and the maintenance of a ROW via the wire-border zone method creates early successional habitat for bird populations (e.g., Yahner et al., 2002b). Thus, because bird species adapted to early successional habitat have experienced population declines over recent decades in the northeastern United States (Robbins et al., 1989; James et al., 1996; Yahner, 2000; 2003a; Askins, 2001; Brawn et al., 2001), a ROW, if properly maintained using the wire-border zone method, represents important nesting habitat for many bird species.

In the present study, we examined the long-term response of breeding birds to ROW vegetation maintenance on SGL 33 in the Allegheny Mountain Region of central Pennsylvania in 2002 and 2003. The objectives of this study were to compare nest abundance, success,

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and placement (1) in handcut versus herbicidal-treated study sites (units) and (2) in wire versus border zones. In addition, results from this study then were compared to those obtained in a previous study conducted on the ROW in 1991–1992 (Bramble et al., 1994) to better understand the long-term effects of ROW maintenance on bird nesting ecology.

METHODS

The wire-border zone method of vegetation maintenance was initiated on the SGL 33 ROW in 1987 (Bramble et al., 1992a) (Fig. 1). This method of vegetation maintenance along a ROW is designed to produce a tree-resistant forb-grass-shrub cover type in wire zones while simultaneously maintaining a tall shrub cover type in border zones. As a result, the wire-border zone method diversifies wildlife habitat on the ROW by creating low-lying vegetation in wire zones and taller vegetation in border zones to produce habitat diversity. The total area of the two zones was approximately equal.

A combination of a low-growing forb-shrub-grass cover type develops in the wire zone, and a tall shrub cover type occurs in the border zone. Adjacent to the border zone is mature forest.

Three principal treatments were assessed on the SGL 33 ROW study sites (units) as follows: handcut (1.2 ha [3.0 acres]), low volume basal spray (1.1 ha [2.7 acres]), and mowing plus herbicide (0.8 ha [2.0 acres]). These were the same units used in a previous study of bird nesting ecology in 1991 and 1992 (Bramble et al., 1994). As time permitted, nest searches were conducted in five other units to give additional data on bird nesting ecology: two low volume basal spray units, a mowing plus herbicide unit, a stem-foliage unit, and a foliage-spray unit.

White oak (*Quercus alba)* was the most abundant undesirable tree species in the handcut unit (both wire and border zones), and northern red oak (*Q. rubra*) was the most common tree in border zones of other units (Yahner et al., 2002a). Red maple (*Acer rubrum*) was a minor component in handcut units, but it was an important tree species in the other units. The most important cover types were forb-grass-shrub in wire zones of all units. Shrubs were the most important cover type in border zones of all units, although forbs also were important in border zones.

In the handcut unit, woody vegetation in the wire zone was cut to a 10-cm (4-inch) height, and trees only were cut selectively in border zones in 2000 (Yahner et al., 2002a; 2002b). In wire zones of herbicidal-treated units, 25% Garlon 4 in 75% basal oil was applied in the same year as a low volume basal spray to all trees and tall shrubs (including witch-hazel [*Hammamelis virginiana*] and bear oak [*Quercus ilicifolia*]) visible above the low herbaceous vegetation. The same low volume basal spray was applied to undesirable trees in border zones, except low-growing trees and shrubs important to wildlife (e.g., witch-hazel and bear oak).

Nest searches were conducted systematically from late May through early August 2002–2003 at 3–4 day intervals in the three principal units and less frequently in the other units. Two to three researchers slowly searched for nests, while watching for parental birds flushing from nests, carrying nest material, or feeding young. When a nest was found, the bird species that constructed the nest, date in which the nest was found, nest location (unit, wire versus border zone, height [cm] above ground), substrate used for the nest, and status of the nest (e.g., number of eggs, etc.) were noted. The status of each nest was monitored at 3–4 day intervals to determine nesting success and was considered successful if at least one young was fledged (Yahner, 1991; Bramble et al., 1994).

Nest predation is the major factor affecting nesting success in most songbird populations (Heske et al., 2001). Potential predators of nests on the ROW included snakes (Yahner et al., 2001a), white-footed mice (*Peromyscus leucopus*) and eastern chipmunks (*Tamias striatus*) (Bramble et al., 1992b; Yahner, 2003b), and a variety of larger mammals (Yahner, 1991; Yahner et al., 2001b). When possible, the type of predator on a nest was determined based on nest appearance and mode of disturbance (e.g., peck holes) (Rearden, 1951; Yahner and Scott, 1988; Hernandez et al., 1997).

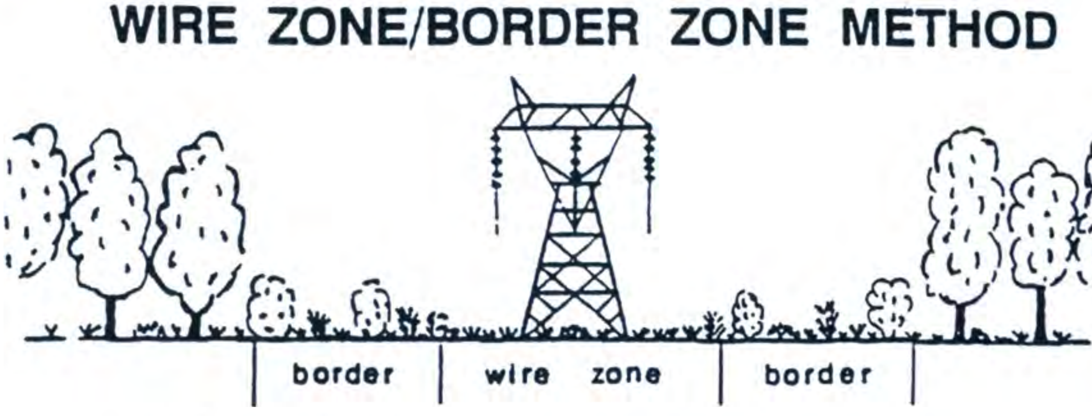

Fig. 1. Diagram of a 230-kV electric transmission line, showing wire and border zones.

Table 1. Nesting bird species and number of nests established (number of nests successfully fledging young in parentheses) in 2002, 2003, and both years combined on the right-of-way on the State Game Lands 33 Research and Demonstration Area, Centre County, Pennsylvania

Bird species	2002	2003	Both years
Indigo bunting (*Passerina cyanea*)	7 (1)	10 (7)	17 (8)
Field sparrow (*Spizella pusilla*)	7 (3)	5 (2)	12 (5)
Gray catbird (*Dumetella carolinensis*)	3 (2)	3 (3)	6 (5)
Eastern towhee (*Pipilo erythrophthalmus*)	5 (2)	1 (1)	6 (3)
Common yellowthroat (*Geothlypis trichas*)	4 (2)	1 (1)	5 (3)
Chestnut-sided warbler (*Dendroica pensylvanica*)	2 (0)	2 (1)	4 (1)
American robin (*Turdus migratorius*)	1 (1)	2 (2)	3 (3)
Red-eyed vireo (*Vireo olivaceus*)	2 (1)	0	2 (1)
Veery (*Hylocichla fucescens*)	1 (0)	1 (0)	2 (0)
Cedar waxwing (*Bombycilla cedrorum*)	1 (1)	0	1 (1)
All species combined	33 (13)	26 (17)	59 (30)

RESULTS AND DISCUSSION

Nest abundance and success

Thirty-three and 26 nests of 10 bird species were noted during 2002 and 2003, respectively (Table 1). The most frequently encountered nests were those of indigo bunting ($n = 17$), field sparrow ($n = 12$), gray catbird ($n = 7$), eastern towhee ($n = 6$), and common yellowthroat ($n = 4$). These species are well adapted to early successional habitats like those created by the wire-border zone method of vegetation maintenance on the ROW (Yahner et al., 2002b). These same bird species were the most common nesting species on the SGL 33 ROW in 1991–92 (Bramble et al., 1994).

We found more nests on the ROW during 2002 compared to 2003, in part, perhaps because of relatively colder ambient temperatures in 2003, which delayed plant phenology and, hence, reduced nest-site availability and concealment for breeding birds (R. Yahner, personal observation). Low ambient temperatures and resultant delays in vegetation growth can retard the onset of nest-building behavior in birds (Pettingill, 1985). Similarly, fewer nests and apparent delays in nest building were observed on another ROW in southeast Pennsylvania in 2003 (Green Lane Research and Demonstration Area, Montgomery County; Yahner et al., 2003).

Only 13 (39%) of 33 nests of all species combined fledged young during 2002 compared to 17 (65%) of 26 nests during 2003 on the ROW (Table 1). No nests were parasitized by the brood parasite, the brown-headed cowbird (*Molothrus ater*) (Yahner, 1995a). Possibly the eastern chipmunk (*Tamias striatus*) may account for higher nest predation in 2002 than 2003. This rodent is known to prey on bird eggs and nestlings and was regionally abundant in 2002 (Yahner, 2003b). Nesting success in 2003 on the SGL 33 ROW was comparable with values reported previously in a variety of habitats (Yahner, 1991).

Forty-two (71% of total) nests were found in the three principal treatment units (Table 2). Clearly, the low volume basal spray unit was more important as nesting habitat than either handcut or mowing plus herbicide units, with nine species nesting in the low volume basal spray unit versus only five species or less in each of the other two units (Fig. 2). Moreover, more than twice the number of nests per area were noted in the low volume basal spray unit (11.4 nest/ha/yr [4.6 nests/acre/year]) than in the mowing plus herbicide unit (5.0 nests/ha/yr [2.0 nests/acre/year]); in turn, the number of nests per area in the mowing plus herbicide unit was 25% greater than that of the handcut unit (3.8 nests/ha/yr [1.5 nests/acre/year]). Thus, based on 2 years of data and results from a previous study (Bramble et al., 1994), we view the low volume basal spray unit as the best nesting habitat and the handcut unit as the least suitable of the three units studied intensively. The low volume basal spray unit was extremely heterogeneous in plant species composition and structure compared to handcut and mowing plus herbicide units (Yahner et al., 2002a; 2002b). Furthermore, in both years, oak sprouts, which were common in the handcut unit, leafed-out quite late compared to other species, making this plant suitable as a nest site only after mid-June.

Table 2. Nesting bird species, number of nests established in both years combined for each of the three principal treatment units, and number of nests per unit area for each unit on the right-of-way on the State Game Lands 33 Research and Demonstration Area, Centre County, Pennsylvania

Bird species	Handcut	Low volume basal	Mowing plus herbicide
Indigo bunting	1	8	3
Field sparrow	0	6	2
Gray catbird	4	2	0
Eastern towhee	1	2	2
Common yellowthroat	0	1	1
Chestnut-sided warbler	0	3	0
American robin	2	1	0
Red-eyed vireo	1	1	0
Cedar waxwing	0	1	0
Total number of species	5	9	4
Total number of nests	9	25	8
Number of nests/ha/yr	3.8	11.4	5.0
Number of nests/acre/yr	1.5	4.6	2.0

Fig. 2. An eastern towhee nest in a low volume basal spray unit (photo taken by R. Yahner, May 2002).

Table 3. Number of nests established per bird species in various plant species on the right-of-way on the State Game Lands 33 Research and Demonstration Area, Centre County, Pennsylvania

Plant species	No. nests	Bird species (no. nests)
Blackberry (*Rubus allegheniensis*)	17	indigo bunting (9), gray catbird (1), eastern towhee (1), chestnut-sided warbler (4), red-eyed vireo (1), veery (1)
Witch-hazel (*Hammamelis virginiana*)	10	indigo bunting (4), gray catbird (1), eastern towhee (1), American robin (1), red-eyed vireo (1), veery (1), cedar waxwing (1)
Blueberry (*Vaccinium* spp.)	8	field sparrow (4), eastern towhee (1), common yellowthroat (2)
Sweet fern (*Comptonia peregrina*)	4	indigo bunting (1), field sparrow (3),
Multiflora rose (*Rosa multiflora*)	3	gray catbird (1), American robin (2)
White oak (*Quercus alba*) sprouts	3	gray catbird (2), eastern towhee (1), indigo bunting (1)
Meadow-sweet (*Spirea alba*)	2	indigo bunting (1), field sparrow (1)
Chestnut oak (*Q. montana*) sprouts	1	gray catbird (1)
Blackberry/sweet fern combined	1	field sparrow (1)
Blueberry/sweet fern combined	1	common yellowthroat (1)
Hay-scented fern (*Dennstaedtia punctilobula*)/ sweet fern combined	1	eastern towhee (1)
Rough goldenrod (*Solidago rugosa*)	1	field sparrow (1)
Rough goldenrod/hay-scented fern combined	1	common yellowthroat (1)
Rough goldenrod/sweet fern combined	1	field sparrow (1)
Gooseberry (*Ribes rotundifolium*)	1	field sparrow (1)
Tartarian honeysuckle (*Lonicera tatarica*)	1	gray catbird (1)
Ground level	1	eastern towhee (1)

Plants used as nest sites

Twelve plant species were used as nest sites (Table 3). The major plants used were blackberry (*Rubus allegheniensis*), witch-hazel, blueberry (*Vaccinium* spp), and sweet fern (*Comptonia peregrina*). Blackberry was common in the wire zone of the low volume basal spray unit, blueberry and sweet fern were common in wire zones of both low volume basal spray and mowing plus herbicide units, and witch-hazel was common in border zones of all units (Yahner et al., 2002a).

Indigo bunting and chestnut-sided warbler (*Dendroica pensylvanica*) preferred blackberry as nest sites (Table 3). Similar findings were noted in 1991–1992 on the SGL 33 ROW (Bramble et al., 1994). Indigo buntings also used relatively small (<1 m [3 feet] in height) witch-hazel for nest placement. On the other hand, nests of field sparrow were found most often in low-growing blueberry and sweet fern. Thus, a diversity of plant species provided suitable nest sites for a diverse breeding bird community on the ROW.

Table 4. Number of nests established per bird species in wire versus border zones in both years combined on the right-of-way on the State Game Lands 33 Research and Demonstration Area, Centre County, Pennsylvania

Bird species	Wire zone	Border zone
Indigo bunting	9	6
Field sparrow	12	0
Gray catbird	2	4
Eastern towhee	3	3
Common yellowthroat	2	3
Chestnut-sided warbler	2	2
American robin	2	1
Red-eyed vireo	0	2
Veery	0	2
Cedar waxwing	1	0
All species combined	33	23

Use of wire zones versus border zones

Thirty-five (59%) of the 59 nests on the SGL 33 ROW were in wire zones, whereas 24 (41%) nests were in border zones (Table 4). A primary reason for most nests occurring in wire zones was the presence of common nests sites (e.g., blackberry, blueberry, and sweet fern). The second most common nesting species, the field sparrow (Table 4), placed nests exclusively in wire zones; thus, if field sparrow nests were eliminated from the data set, approximately the same number of nests occurred in wire versus border zones (23 vs. 24 nests, respectively) (Table 4). As nesting habitat, therefore, we strongly recommend that border zones be established on a ROW, which in combination with wire zones (Fig. 1), provide abundant and diverse nest sites for the nesting bird community (Bramble et al., 1994; Yahner et al., 2002b).

CONCLUSIONS

The State Game Lands 33 Research and Demonstration Area continues to provide nesting habitat for a variety of bird species. Native vegetation (shrubs and forbs) in both wire and border zones serves as excellent nest sites. Compared to other units, low volume basal appears to be a very good location for placement of bird nests. However, given the probability of a "blackout" of electrical power if wires come in contact with tall trees, mowing plus herbicide treatment on a ROW may be the best application in terms of cover-type development in wire zones, resistance to seedling invasion of undesirable trees, and its value as wildlife habitat (e.g., Bramble et al., 1990). Cover type in mowing plus herbicide units consists of a grass-forb-shrub combination, which has restricted tree invasion to 185 trees/ha (75 trees/acre) compared to 495 trees/ha (200 trees/acre) in other units on the SGL 33 ROW (Yahner et al., 2002a). This study and others (e.g., Bramble et al., 1992a; Yahner et al., 2002b) have shown that mowing plus herbicide is simultaneously valuable to many wildlife species.

High rates of nesting success on the ROW, particularly in 2003, attest to the fact that this linear corridor of early successional habitat does not result in a dramatic increase in rates of nest predation (Gates and Gysel, 1978; Yahner, 1995a; 1995b; 2000). Instead, because early successional habitat is becoming less common in the eastern United States (Trani et al., 2001) and because species dependent on these habitats are showing populations declines in recent decades (Yahner, 2000; 2003a; Askins, 2001; Brawn et al., 2001), the maintenance of a ROW via the wire-border zone method is extremely valuable to the long-term, regional conservation of early successional species. For instance, indigo bunting and field sparrow, which are the two most abundant species nesting on the SGL 33 ROW, are among the bird species showing significant statewide population declines according the breeding bird surveys conducted by the U.S. Fish and Wildlife Service, who's website is: (http://www.mbr-pwrc.usgs.gov/bbs/bbs/html).

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REFERENCES

Askins, R.A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildl. Soc. Bull., 29: 407–412.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1990. Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way. J. Arboric., 16: 130–135.

Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1992a. Breeding-bird population changes following right-of-way maintenance treatments. J. Arboric., 18: 23–32.

Bramble, W.C., R.H. Yahner, W.R. Byrnes, and S.A. Liscinsky. 1992b. Small mammals in plant cover types on an electric transmission right-of-way. J. Arboric., 18: 316–321.

Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1994. Nesting of breeding birds on an electric utility right-of-way. J. Arboric., 20: 124–129.

Brawn, J.D., S.K. Robinson, and F.R. Thompson, III. 2001. The role of disturbance in the ecology and conservation of birds. Ann. Rev. Ecol. System., 32: 251–276.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology, 59: 871–883.

Hernandez, F., D. Rollins, and R. Cantu. 1997. Evaluating evidence to identify ground-nest predators in west Texas. Wildl. Soc. Bull., 25: 826–831.

Heske, E.J., S.K. Robinson, and J.D. Brawn. 2001. Nest predation and neotropical migrant songbirds: piecing together the fragments. Wildl. Soc. Bull., 29: 52–61.

James, F.C., C.E. McCullough, and D.A. Wiedenfeld. 1996. New approaches to the analysis of population trends in land birds. Ecology, 77: 13–27.

Pettingill, O.S., Jr. 1985. Ornithology in laboratory and field. Fifth edition. Academic Press, Orlando, Florida. 403 pp.
Rearden, J.D. 1951. Identification of waterfowl nest predators. J. Wildl. Manage., 15: 386–395.
Robbins, C.S., D.K. Dawson, and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic states. Wildl. Monogr., 103: 1–34.
Trani, M.K., R.T. Brooks, T.L. Schmidt, V.A. Rudis, and C.M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildl. Soc. Bull., 29: 413–424.
Vistas. 2003. 50 years of biodiversity research. Vistas, 16(1): 1–10.
Yahner, R.H. 1991. Avian nesting ecology in small even-aged stands. J. Wildl. Manage., 55: 155–159.
Yahner, R.H. 1995a. Forest-dividing corridors and Neotropical migrant birds. Conserv. Biol., 9: 476–477.
Yahner, R.H. 1995b. Forest fragmentation and avian populations in the Northeast: some regional landscape considerations. Northeast Wild., 52: 93–102.
Yahner, R.H. 1997. Long-term dynamics of bird communities in a managed forested landscape. Wilson Bull., 109: 595–613.
Yahner, R.H. 2000. Eastern Deciduous Forest: Ecology and Wildlife Conservation (2nd ed.). University of Minnesota Press, MN. 256 pp.
Yahner, R.H. 2003a. Terrestrial vertebrates in Pennsylvania: status and conservation in a changing landscape. Northeastern Nat., 103: 343–360.
Yahner, R.H. 2003b. Population trends in eastern chipmunks: implications to avian nesting success. J. Pa. Acad. Sci., 76: 62–66.
Yahner, R.H., R.J. Hutnik, and S.A. Liscinsky. 2001a. Effect of vegetation maintenance of an electric transmission line right-of-way on reptile and amphibian populations. J. Arboric., 27: 24–28.
Yahner, R.H., R.J. Hutnik, and S.A. Liscinsky. 2002a. 50 Years of Continuous Study: 1953–2002 – State Game Lands 33 Research Project. Annual Report to Cooperators. 40 pp.
Yahner, R.H., R.J. Hutnik, and S.A. Liscinsky. 2002b. Bird populations associated with an electric transmission right-of-way. J. Arboric., 28: 123–130.
Yahner, R.H., R.J. Hutnik, and S.A. Liscinsky. 2003. Green Lane Research and Demonstration Project: 17 years of continuous study. Annual Report to Cooperators. 28 pp.
Yahner, R.H., A.D. Rodewald, and S.C. Talbott. 2001b. Edge-related nest predation associated with the retention of residual trees in harvested hardwood stands. Can. Field-Nat., 15: 82–87.
Yahner, R.H. and D.P. Scott. 1988. Effect of forest fragmentation on depredation of artificial nests. J. Wildl. Manage., 52: 158–161.

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Mitigation of Woodpecker Damage to Power Poles in British Columbia, Canada

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Wooden utility poles are subject to damage by woodpeckers. Their excavations are thought to advance premature wood decay and often occur near support bracing so as to weaken the structural integrity of the pole. On one transmission line in the Caribou region of central British Columbia, 14.1% of all poles examined ($n = 1{,}097$) sustained various degrees of damage, ranging from superficial excavations to multiple 0.6-m deep cavities in one pole. Among the damaged poles, 38.7% (60 poles) contained cavities. The median height of cavities was 8.3 cm with more cavities tending to occur at or near the lower attachment of the cross brace between adjacent H-frame poles. Damaged poles with cavities were aggregated into focal areas along the line as a function of the age and canopy composition of the surrounding forest. During the breeding season, we located 57 active nest cavities associated with these focal areas both on rights-of-way and in the surrounding forest. Although just over half of these nests (32 = 56%) belonged to woodpeckers comprising 8 different species, none of their nests were found in power poles. Only secondary cavity nesters, including tree swallow (*Tachycineta bicolor*) and mountain bluebird (*Sialia currocoides*), were observed using cavities in poles for nesting. Examination of a province-wide database on woodpecker damage revealed that most damage by far was located in the drier IDF (Interior Douglas-fir) zones in the southern part of the province. A mitigation strategy to reduce structural damage to poles and associated maintenance costs might be found in: 1) greater awareness of the habitat potential for woodpeckers in forest stands adjacent to rights-of-way, 2) adoption of deterrent strategies on sections of right-of-way with woodpecker cavity issues, and 3) relocation of a few damaged poles at strategic locations along or just outside the right-of-way.

Keywords: Woodpecker, cavity, power poles, mitigation, acoustic deterrents, forest habitat management, right-of-way

Wooden utility poles are subject to recurrent damage by cavity builders, namely woodpeckers. Woodpeckers and other primary cavity users build cavities in trees and snags in the forest, but a power pole adjacent to a rich source of food may serve their needs quite adequately. These birds also forage for insects and other invertebrates on snags in the forest that resemble power poles. Although cavity damage is of greater concern because of its weakening effect upon structural integrity, surface and interior damage to power poles through foraging by pileated woodpeckers can pose a potential safety concern. Based on these considerations BC Hydro monitors the status of woodpecker damage to poles and replaces approximately 0.1% of all wooden transmission poles on an annual basis (Taylor, 2001).

To gain some perspective of the cost and nature of woodpecker damage to power poles, Taylor (2001) conducted a review of the situation involving both transmission and distribution poles in the Northern Interior Region of B.C. Transmission lines carry power regionally between substations, typically in the range of 60 to 500 kV. Steel towers generally support the high power lines at 500 kV, but wooden poles are normally used for 60, 138 and 230 kV lines. Distribution lines carry power in the range of 4 to 35 kV from

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

Table 1. Woodpeckers of British Columbia

Species	Common name	Status	Location
Melanerpes lewis	Lewis's woodpecker	B	Okanagan – Thompson
Sphyrapicus thyroideus	Williamson's sapsucker		
S. t. thyroideus		B	Similkameen – Okanagan
S. t. nataliae		R	Columbia Basin
Sphyrapicus varius	Yellow-bellied sapsucker	Y	Eastern – central B.C.
Sphyrapicus nuchalis	Red-naped sapsucker	Y	Eastern – south central B.C.
Sphyrapicus ruber	Red-breasted sapsucker	Y	Coastal – central B.C.
Picoides pubescens	Downy woodpecker	Y	Throughout B.C.
Picoides villosus	Hairy woodpecker	Y	Throughout B.C.
P. v. picoideus		B	Queen Charlotte islands
Picoides albolarvatus	White-headed woodpecker	R	Similkameen – Okanagan
Picoides tridactylus	Three-toed woodpecker	Y	Throughout B.C.
Picoides arcticus	Black-backed woodpecker	Y	Throughout B.C.
Colaptes auratus	Northern flicker	Y	Throughout B.C.
Dryocopus pileatus	Pileated woodpecker	Y	Throughout B.C.

R = Red-listed species or subspecies (extirpated, endangered or threatened status in B.C.); B = Blue-listed species or subspecies (vulnerable to human activities or natural events); Y = Yellow-listed species (indigenous species that are not at risk in B.C.).

house to house, representing the majority of poles in the total power grid. Among 203,678 distribution poles and 15,783 transmission poles in the Northern Interior Region, all wooden structures consisting of either western red cedar or lodgepole pine, ca 0.015% and 0.089% of these poles respectively are replaced each year. At a cost of $9,000 per pole in 1992, Manitoba Hydro replaces 8–10 transmission poles annually in that province (McIlraith and Berger, 2000). This compares with 14 poles for the Prince George transmission area alone, and somewhere in the range of 30 distribution poles for the 3 northern region areas in the middle of the province.

All species of woodpecker are capable of excavating cavities in snags and trees and as such they are termed primary cavity users. Two other groups of birds, namely the nuthatches and chickadees, are also capable of creating their own cavities. Some cavity excavators resort to a variety of means to make cavity building easier. For example, those species of woodpecker with smaller bill structure, such as three-toed woodpecker together with chickadees and nuthatches, may be very adept at finding weaknesses on tree trunks and branches where heart rot has softened the interior wood. Three-toed woodpeckers often select recently broken snags and place their cavity near the point of breakage, where heart rot decay is often the basis for breakage. This makes it easier and faster to hollow out a cavity in time for the female to put down her eggs. While only a select group of cavity users are capable of building nest cavities, the majority of species that use cavities are termed secondary cavity users because they rely on existing natural holes or hollows in large trees, or cavities excavated by primary cavity users.

There are 12 species of woodpecker endemic to the province of British Columbia (Table 1). The BC Conservation Data Centre, which is the provincial body that assigns ratings of relative risk of extinction for plants and animals in the province, lists three species. Lewis's woodpecker and Williamson's sapsucker are both blue-listed (not immediately threatened); white-headed woodpecker is red-listed (endangered or threatened under the *Wildlife Act*). All other species are yellow-listed (includes both common and uncommon species).

Objectives of this study were to ascertain which species of woodpeckers are causing damage to poles and the basis for cavity excavation and other kinds of damage, and to devise an approach for mitigation of the problem in a manner that would not drive the birds away from their habitat.

METHODS

Assessment of pole damage along line 2L352 in Central British Columbia

The study area was located at 52° N and 122° W at an average elevation of 940 m at Williams Lake (Fig. 1). In 2002, we examined transmission line 2L352, which runs north from 100-Mile House over a distance of 104 km to Soda Creek. Parts of line 2L94, which intersect with this line at Soda Creek, were also included. We determined the type of damage (surface foraging vs. cavity excavation), size, height, number and orientation of holes on the pole. Mean and/or median values ± standard errors are reported. Conformity of mean heights to a normal distribution was generally tested by comparing a frequency histogram of observed versus expected classes based on the mean and standard deviation. The tail-end bins were combined to produce at least 5 per class, providing there was no indication of outstanding skewness (Krebs, 2001). Deviation from expected was determined in a Chi-square Goodness-of-fit test. The mean number of cavities per

The map shows the location of IDF zones of south central British Columbia ( ) and transmission line 2L352 (white line along the north eastern edge of IDFdk3) relative to the entire province ( ).

Fig. 1. Interior Douglas-fir (IDF) zones of the province of British Columbia.

pole and the mean number of cavities per kilometer of transmission line were tested against random occurrence as predicted by Poisson. As in the previous case, tail-end bins were combined and deviation from Poisson was determined in a Chi-square Goodness-of-fit test. Cavity orientation was tested against 8 possible directions, differing by 45 degrees.

The forest surrounding line 2L352 is primarily situated in Interior Douglas-fir zone IDFdk3 with one 20 km stretch of sub-boreal pine – spruce SBPSmk (Fig. 1). We characterized the age class and canopy character of the forest next to the line into the following categories: old (>160 years), mid-seral (40–160 years) and young (less than 40 years); and pure Douglas-fir, sub-boreal pine – spruce, mixed-wood forest, agricultural pasture amid Dougals-fir (disturbed), and regenerating stands after wildfire or clearcut logging (disturbed). Aspen groves were frequent in disturbed areas, particularly the agricultural zones, and less common in the older stands. We compared the frequency of cavities on the transmission line against the available number of poles through six age classes, excluding those sections next to disturbed zones where logging or clearing for pasture created an ambiguous mixture of forest stands. We also used the frequency of large diameter stumps on the right-of-way to gauge the occurrence of older trees in the surrounding forest. This approach was still feasible since removal of stumps from the right-of-way had not begun until quite recently. This measure allowed for better depiction of patchy distribution patterns of old stands of trees, including isolated veteran trees, augmenting the previous analysis where age structure of the surrounding forest was more clearly defined on both sides of the line. We used a G-test with William's correction to compare cavity occurrence in power poles and woodpecker activity in the adjacent forest between sections of transmission line with low stump density and sections with higher stump density.

Evaluation of nesting activity in cavities along line 2L352

Nest cavities were located in 2003 through systematic search of aspen-dominated groves on either side of line 2L352 and in wooden power poles on this line. We concentrated the nest search on the focal areas of woodpecker activity identified on the transmission line in the previous year. The nest search was approximately balanced between the transmission line and the surrounding aspen patches, however, considerably more cavity substrates were found in the forest compared to the power poles spaced 200 m apart on the transmission line. Hence, we used the secondary cavity nesters to calibrate the sampling effort assuming that they select all woodpecker cavities in forest edge or in power poles based on their availability.

Province-wide assessment of woodpecker damage to transmission poles

We summarized woodpecker damage across the entire province (with the exception of the Peace region, where data were incomplete) based on a transmission line database (System Transmission Asset Recording and Reporting or STARR, 2003). Total distance of the lines was estimated from the provincial transmission system map. The database provides an ongoing summary of pole condition across the integrated power grid of the province, where damage by woodpeckers and other agents is ranked as follows: A) no damage, B) superficial damage (e.g., foraging holes or enlargement of cracks by woodpeckers), C) deeper pole penetration (e.g., cavity excavation by woodpeckers), which may require pole replacement depending upon the position of damage relative to bolts and support braces, D) multiple cavities per pole, and E) serious structural damage to the pole with evidence of pole decay; pole should be replaced. A damage index was calculated from the number of poles with more extensive damage (rankings "C" through "E") relative to the total distance of lines per region. The average action index for each region is a measure of the frequency of recommended pole replacements (generally those poles with the highest damage ratings, or any damage near support structures) per total distance of transmission line in the region. The average values per region are interrelated by the following expression:

$$\frac{\text{Damage}}{\text{km}} \times \frac{\text{Action}}{\text{Damage}} = \frac{\text{Action}}{\text{km}}.$$

RESULTS

Characteristics of pole damage along line 2L352 in Central British Columbia

A total of 1,097 poles were examined on line 2L352 and part of line 2L94 between June and October 2002. Among this total, 155 poles (14.1%) sustained various degrees of damage by woodpeckers. Much of the damage could be ascribed to foraging excavations of pileated woodpeckers. Some of these holes may represent the beginnings of a nest or roost cavity. These sorts of excavations are more-or-less superficial in nature and are not serious from a structural perspective.

Sixty poles (5.5% of the total poles examined) or just over one-third (38.7%) of the damaged poles on this line contained cavities within the pole. The average height of cavity entrance holes ($n = 82$) on the poles was 8.71 ± 0.30 cm (median, 8.30 cm). The total here was greater than the number of poles bearing cavities, indicating that some poles bear more than one cavity. A test for a normal distribution of cavity heights revealed slight right-handed skewness (i.e., more values were above the mean than below). The distribution deviated, however, from normality ($p = 0.04242$) mainly because there was some degree of bimodality around 7 and 10 cm. Since this corresponds approximately to where the crossbraces attach between the two poles, it would appear that there is some positive influence of the crossbraces on the location of cavities.

The average height of holes and foraging excavations was lower on the pole at 7.19 ± 0.23 cm (median, 7.00 cm) compared to cavity height. This set of values is apt to include false cavity starts mixed with foraging excavations at all levels of the pole. There were a significant number of excavations at lower pole heights (e.g., 2 m) and more excavations than expected at 7 m, however, the distribution did not deviate significantly from a normal distribution.

The average number of cavities per pole was 1.90 ± 0.26 (median, 1.00) with a range of 1 to 12. A comparison of the average number of cavities per pole with that expected for random selection based on a Poisson distribution revealed significant deviation ($p < 0.0001$) due to a considerable excess of poles without cavities (i.e., 1,037 poles) and only a narrow range of poles with cavities. Among poles with cavities with a mean value of 1.90, there were disproportionately more poles with only 1 cavity per pole and right-handed skewness caused by 3 poles with 7, 9 and 12 cavities per pole. These observations indicate that poles are not chosen randomly for excavation of nest/roost cavities and, as we shall see later, poles that are chosen tend to be clustered in the same general location.

There were disproportionately more north and north-west facing cavities ($p < 0.0001$) along this line, as was the case for holes and feeding excavations. This apparent bias of the orientation of cavities corresponded with the north – south orientation of the transmission line.

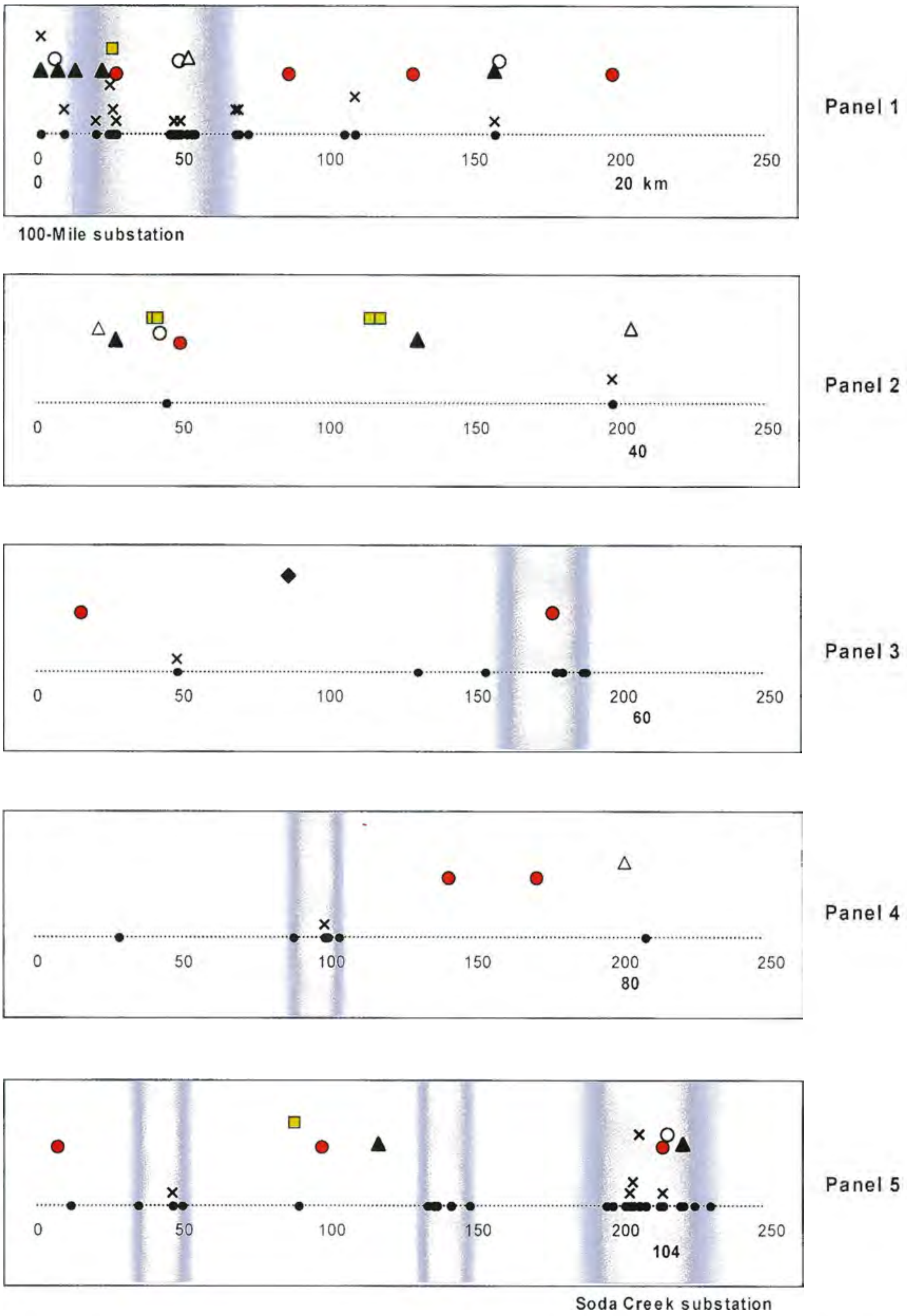
Aggregation of pole damage on line 2L352

Figure 2 depicts the distribution of poles with cavities together with woodpecker sightings along transmission line 2L352. The abscissa shows the entire 104-km line from 100-Mile substation to Soda Creek substation in 5 panels. Each panel represents 100 pairs of poles (i.e., 200 poles) through a distance of 20 km. Sections of the transmission line with cavities are numbered in boldface, according to distance (km) from the 100-Mile substation. Woodpecker activity at the Soda Creek substation also includes poles from line 2L94 (Sections 139 and 140), which intersected with line 2L352 at 103 km. The ordinate reveals poles with more than one cavity per pole with "**x**" above the solid circle (Maximum = 12 for one pole at Soda Creek substation). Focal areas for cavity excavation in power poles are shaded. Seven species of woodpecker and sapsucker were detected in the study area between June 19 and October 30, 2002, six of which were found in the forest adjacent to line 2L352. An additional species, the black-backed woodpecker, was observed along line 2L94 at 122 km.

The data reveal that poles with cavities were clustered so that focal areas of damage by woodpeckers were interspersed by relatively large sections of right-of-way with undamaged poles. The mean number of poles with cavities per km of transmission line for 2L352 was 2.27 ± 0.55. Cavity excavation at either end of line 2L352 (i.e., near the substations) was significantly higher ($p < 0.0001$) than the intervening portion of line. These focal areas also tended to sustain multiple cavities per pole. When we removed the high activity values at the ends of the line to address whether the intervening focal areas alone had significantly more cavities than the rest of the line we found that 2 out of the 4 focal areas, specifically those at 55–60 km and 97–98 km, still gave significant deviation from Poisson ($p = 0.000209$). The other two focal areas had too few poles with cavities to conclude significance.

Almost all the cavities in poles of this line were large with oval-shaped entrances having a longer vertical axis of 10–12 cm. Cavities of this dimension in the upper 50–70% of pole height are typical of pileated woodpecker. These woodpeckers were often encountered in these forests foraging for carpenter ants (*Camponotus* spp).

A higher fraction of cavities in power poles occurred in focal areas situated next to older forest ($p = 0.02822$), with trees greater than 160 years old on both sides of the line. Sections of the line that passed through younger regenerating stands had as many cavities in power poles as would be expected through chance in these sections of the line; whereas sections of line that adjoined mid-seral forest, especially a 20-km section through a sub-boreal pine spruce zone (SBPSmk) had fewer cavities than expected. Woodpecker sightings and poles with cavities were highest at either end of the line, through no particular influence of the substations. The Soda Creek substation is situated in



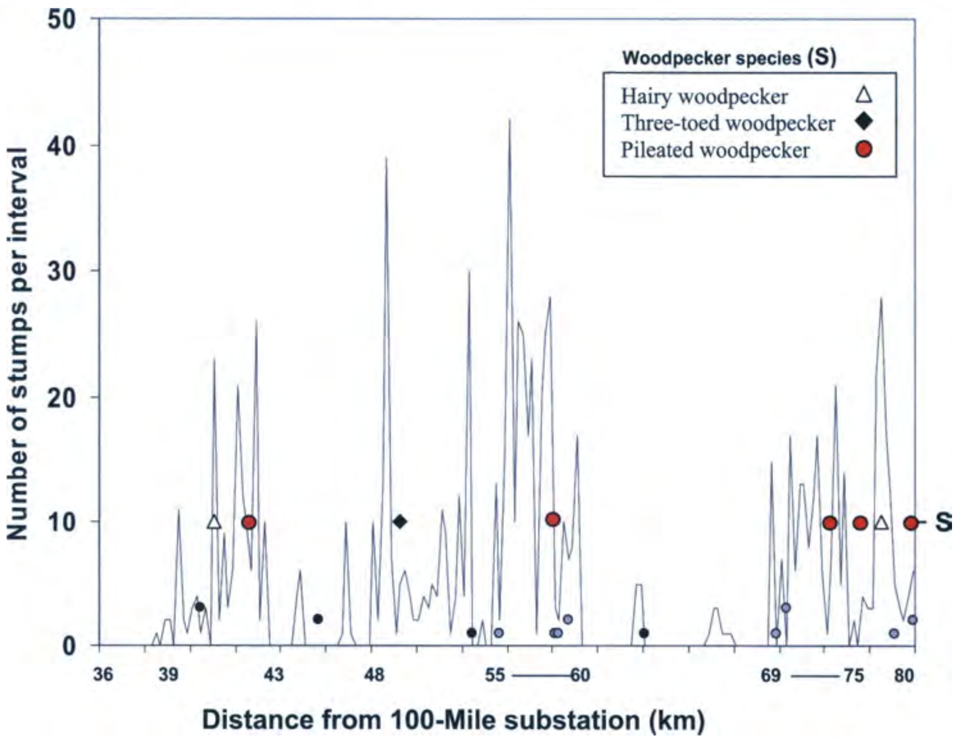
The abscissa depicts the entire 104-km transmission line (2L352) from 100-Mile substation to Soda Creek substation and poles with cavities (•) along this line. The ordinate reveals poles with more than one cavity per pole with "x" above the corresponding circle. Focal areas for cavity excavation in power poles are shaded. Sightings of different woodpecker species along the line are indicated as follows.

Fig. 2. Distribution of cavities and woodpecker sightings along transmission line 2L352.

ancient stands of pure Douglas-fir, offering prodigious foraging opportunity for pileated woodpeckers. At the south end of the line, the landscape is more agricultural with extensive pasture amid isolated patches of Douglas-fir. Cavity damage was not always situated next to older forest. For example, one 10-km stretch of mixed-wood forest harboring the oldest trees of the entire line did not have any cavities in the poles along this section of line. Apart from the above-mentioned zone in SBPSmk, the entire line was located in one of the Interior Douglas-fir biogeoclimatic zones (IDFdk3) that typify much of the southern interior of British Columbia.

Influence of stumps upon pileated woodpecker activity on rights-of-way

Large-diameter stumps from old forest trees that were cut when the rights-of-way were created influenced woodpecker activity on the right-of-way long afterward. We counted the number of stumps (diameter >0.4 m) and checked for evidence of foraging by pileated woodpeckers in the stumps between kilometre 36 and 81 of line 2L352 (Fig. 3). Over this stretch of forest the median number of stumps per 200 m section of right-of-way was 2.0. The distribution of large-diameter trees, however, was aggregated as indicated by the line plot in Fig. 3, with some sections tabulating as many as 42 stumps per hectare, especially along riparian margins. Closer inspection of the distribution pattern of old trees in Fig. 3 revealed 5 sections with 0.54 ± 0.19 stumps/ha through a total distance of 22.6 km, and 5 sections with 8.06 ± 1.25 stumps/ha through 23.2 km. Thirteen poles bore cavities in the latter sections of the transmission line compared to 2 for the former sections ($G = 8.45$, $p = 0.00366$). There were also more woodpeckers scored in the surrounding forest for the latter sections (7) compared to the former sections (2) ($G = 4.62$, $p = 0.03165$). The presence of large-diameter stumps on the right-of-way is apt to correlate with woodpecker activity because it generally means that the adjacent forest had large old trees like those that were cut when the right-of-way was constructed. Moreover, we found that virtually every stump on the right-of-way contained various species of large wood ants, with evidence of forage by pileated woodpeckers. Some of the stumps were virtually leveled probably due to the combined effects of foraging by woodpeckers and black bears. Thus both the original forest and the cut stumps contain foraging substrates that will attract these birds.



The relative density of large-diameter stumps is indicated by the line graph, wherein the ordinate depicts the number of large-diameter cut stumps (>0.4 m) per 200 m interval counted between kilometre 36 and 81 along transmission line 2L352; and the abscissa shows the position of these intervals in terms of distance (km) from 100-Mile substation. The locations of cavities in these intervals are represented by small circles, wherein the ordinate assumes values of 1, 2 or 3 cavities per pole. Large oval-shaped cavities excavated by pileated woodpeckers (●) are distinguished from smaller cavities (•). The locations at which different woodpecker species (**S**) were sighted in the adjacent forest are indicated in the legend, using the same symbols as in Fig. 2.

Fig. 3. Distribution of cavities and cut stumps along transmission line 2L352.

Cavity-nesting activity along line 2L352

A systematic search for active nest cavities and nest-tending activities of primary and secondary cavity nesters was conducted on lines 2L352 and 60L352 during the peak of the breeding season (June 6–July 11, 2003). Among 57 active nest cavities found, 44 belonged to primary cavity nesters of which 32 were those of woodpeckers (14 red-naped sapsucker, 8 northern flicker, and 10 nests among 6 other species including 2 for pileated woodpecker). All 44 nest cavities for this group were located in the landscape, especially aspen groves, next to the transmission line; none were observed in power poles. Secondary cavity nesters including tree swallow (Tachycineta bicolor) and mountain bluebird (Sialia currocoides) occupied the remaining 13 nest cavities, 4 of which were in power poles. Since the secondary cavity nesters will use cavities for nesting commensurate with their availability (Holt and Martin 1997) observations of nesting birds in this group may be used to calibrate the sampling effort in the forest relative to the transmission line. With this calibration of the total substrates evaluated, we should have expected to see at least 10 active woodpecker nests in power poles, including 3 flicker nests, if woodpeckers are using the power poles for nesting.

Aggregation of pole damage province-wide

To gain perspective on pole damage by woodpeckers throughout the province, we compared a province-wide database which monitors the ongoing condition of transmission poles (including woodpecker damage) against the biogeoclimatic zones associated with each line (Table 2). The biogeoclimatic zones of all the transmission lines were readily identified by comparing BC Hydro's transmission system map against BEC Web maps, available as interactive PDF's (http://www.for.gov.bc.ca/hre/becweb/mapping.htm), which allow the user to effectively zero in on any particular area of the province.

Damage to power poles of all types is recorded and tracked in the STARR database. The damage is ranked on a scale from "A" (no damage) to "E" (severe damage likely to result in pole failure). As poles are replaced from year to year across the lines damaged, additional poles are recommended for replacement as factors such as weathering, decay and further enlargement of cavities (especially excavation of multiple cavities per pole) by woodpeckers contribute to the "ripening" of new "D" and "E" category poles. When action is not commensurate with the assessed damage across a given line, the damage accumulates and this can be anticipated to incur higher costs associated with a larger action index to restore structurally sound poles to the line.

The number of damaged poles and the total distance of the principal transmission lines evaluated in eight regions are shown in the first three columns (Table 2). Note that the average frequency of damage per line does not quite correspond to the ratio of values in column 2 to column 3 because we include all poles with any reported damage in column 2. The regions with the greatest impact by woodpeckers are listed from highest to lowest based on the damage index in column 4.

Transmission regions of the province that were largely comprised of Interior Douglas-fir (IDF) zones, such as the North Thompson, Okanagan-Similkameen and Cranbrook regions, had the greatest damage by woodpeckers. Figure 4 illustrates this point further through a ranked comparison of the damage index of different lines taken from the North Thompson and Prince George transmission regions, the latter of which is largely representative of sub-boreal spruce (SBS) zones. These two regions had the highest total distance of transmission lines in the province but the North Thompson had nearly 4-fold more damage than the Prince George region.

The damage index represents the frequency of damage (i.e., number of C, D and E category poles as described in the text) per km of line. Values for different lines in each region are ranked from highest to lowest along the abscissa.

DISCUSSION

Basis for cavity excavation in power poles

The evidence that we have gathered from examination of cavities in power poles on transmission line

Table 2. Summary of damage and planned replacements for transmission regions in British Columbia

Region	Number of poles damaged by woodpeckers	Total length of right-of-way (km)	Average damage index	Action/ damage	Mean action index
North Thompson	598	1,581	0.341	0.106	0.036
Okanagan–Similkameen	78	658	0.111	0.288	0.032
Cranbrook	291	724	0.098	0.268	0.026
Lower Mainland	168	429	0.092	0.150	0.014
Prince George	139	1,008	0.089	0.162	0.014
Fraser Valley	73	280	0.082	0.174	0.014
Vancouver Island	68	677	0.056	0.211	0.012
Terrace	6	397	0.003	0.000	0.000
All	**1,421**	**5,754**	**0.109**	**0.170**	**0.019**

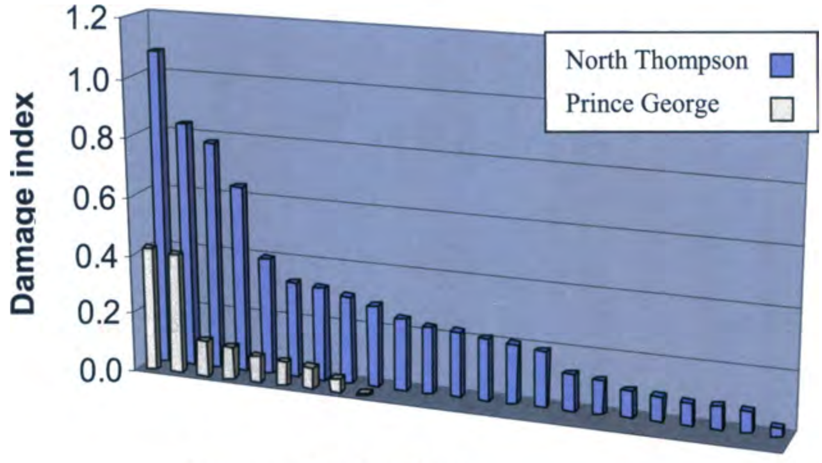


Fig. 4. Comparison of the damage index for transmission lines from the North Thompson and Prince George transmission regions of British Columbia.

2L352 suggests that most of the damage is due to pileated woodpecker. The large size and shape of the cavity entrance and position of cavities in the upper third of the pole height typifies this species (Bull, 1987; Martin et al., 2004). In addition, no other species of woodpecker mines for insects deeply into the substrate like pileated woodpecker (Conner, 1979; Bull and Holthausen, 1993). Foraging excavations by pileated woodpecker typified much of the damage to power poles.

Throughout several years of observing cavities on power rights-of-way in central and northern British Columbia, and on the Queen Charlotte Islands, no woodpeckers were ever observed actively nesting in power poles (Taylor, 2001; 2002; Parker, 2003; 2004). Although it is certain that woodpeckers were the excavators of cavities in power poles it is not known when the cavities were excavated and for what purpose, especially whether they were ever used as nests. A systematic search for cavities in power poles and in the landscape surrounding the right-of-way in 2003 revealed active cavities for all the anticipated species of woodpeckers, nuthatches and chickadees (primary cavity builders) for the region, though exclusively in natural substrates within the surrounding landscape; none were in power poles. Only secondary cavity users, namely tree swallow (*Tachycineta bicolor*) and mountain bluebird (*Sialia currocoides*), were seen to be actively nesting in cavities of power poles (Parker, 2004). Nest cavities of northern flicker are often excavated in isolated snags without much in the way of surrounding forest cover, similar to the habitat context of the power poles on the rights-of-way (Warren et al., 2005), or in aspen groves. Pileated woodpeckers favour interior forest for nesting or an aspen grove (Harestad and Keisker, 1989; Aubry and Raley, 2002). While cavity excavation by woodpeckers in power poles was not commensurate with nest cavity excavation in the surrounding landscape for the limited period of our study, Dennis (1964) notes that several species of woodpeckers, including northern flicker and pileated woodpeckers, do use cavities in power poles for nesting. Observations of nesting woodpeckers in power poles in different parts of North America is apt to vary depending upon the availability of suitable substrates in the surrounding landscape. In Interior Douglas-fir forests of southern British Columbia, woodpeckers select trembling aspen and little else as a preferred nesting substrate because of its proclivity for heartwood decay (Harestad and Keisker, 1989; Martin et al., 2004). Detailed study of the characteristics of roost and nest cavities has revealed that pileated woodpeckers select different kinds of trees for roosting and nesting, as influenced by habitat context (Bull et al., 1992; Aubry and Raley, 2002). In coastal Oregon, large diameter western red cedar snags (dbh, 155–309 cm) are strongly favoured, especially when they contain hollow chambers caused by heart rot fungi (Aubry and Raley, 2002). Pileated woodpeckers will roost in vacated nest cavities though less often than roost cavities specifically excavated for this purpose (Bull et al., 1992). Roost cavities are often positioned in close proximity, like the clustered arrangement found on the rights-of-way. This affords them opportunity for escape from various mammalian predators (Bull et al., 1992; Aubry and Raley, 2002). Thus, we surmise that cavities in power poles at the present time are used primarily for roosting and predator surveillance (cf. nesting), which we observed on several occasions for both pileated woodpecker and northern flicker.

Cavities were excavated close to or just under the attachment of the crossbrace, as widely observed throughout North America (Dennis, 1964). We also found that cavities were oriented in the same direction as that of the transmission line. The north-facing directional bias was not consistent with other findings (Dennis, 1964; McIlraith and Berger, 2000). If there was correlation of these findings with predator surveillance, it might be useful to compare cavity orientation for lines that run primarily east – west versus north – south. Cavities with a north-facing direction would offer the birds the longest sweeping view down the line of the right-of-way away from the glare of the sun. In keeping with this idea, it may also prove to be the case that woodpeckers may select poles on heights of land with cavities directed towards the largest vistas from these vantage points.

Mitigation of woodpecker damage to power poles

Northern temperate forests of Canada are dynamic ecosystems, subject to disturbance by wildfire, insect epidemics, human settlement and harvesting for timber. These sorts of factors alter the distribution patterns of woodpeckers in the forests and influence the likelihood of damage to power poles on rights-of-way. For this reason, we are inclined to develop a more flexible strategy for mitigating woodpecker issues, one with measures that could treat the problem in focal areas of concern and subsequently be moved to other locations.

Our approach to mitigating damage to power poles rests upon understanding woodpecker behavior and the basis for cavity excavation in utility poles. An effective approach to mitigating structural damage to poles and associated maintenance costs might consider the following:

1. habitat potential for woodpeckers in forest stands adjacent to rights-of-way;
2. adoption of deterrent strategies on sections of right-of-way with woodpecker cavity issues; and
3. retention of damaged poles at strategic locations along rights-of-way.

Habitat potential of forest stands next to rights-of-way

The habitat context of the landscape surrounding power rights-of-way is an important consideration in relation to woodpecker activity and their behavioral response to wooden power poles. Throughout the province the most extensive damage to wooden power poles occurred in the dry Douglas-fir biogeoclimatic zones. Our study revealed that damage was aggregated along those sections of transmission line where mature Douglas-fir stands predominate. A prime example of this was found along the northern section of line 2L352 where climax Douglas-fir on either side of the line offered high foraging potential but not much deciduous tree content for cavity excavation. Western red cedar poles on the right-of-way may support the foraging activities of pileated woodpeckers in these pure Douglas-fir stands by providing a convenient substitute for aspen or cottonwood poplar in which to establish roosting sites. We also saw extensive damage to poles next to agricultural landscapes and in forests regenerating from wildfire. These areas provide patches of old forest with good foraging potential for pileated woodpeckers and other species. Sections of transmission line with little or no damage to power poles included younger forests with limited foraging potential and climax stands of mixed-wood forest with wide availability of suitable substrates for cavity excavation.

Historically, the landscapes throughout much of North America, including those of central British Columbia, were influenced by large-scale fire disturbance. This type of disturbance together with smaller-scale events influenced the landscape pattern and distribution of habitat elements. Studies in the interior part of British Columbia have shown that many woodpecker species establish nesting territories in elements of habitat that resemble those caused by fire disturbance (Aitken, 2002; Aitken et al., 2002). Woodpeckers also respond to disturbance fairly promptly by relocating to forests that have been recently burned or killed by beetle attack (Crockett and Hansley, 1978; Hoyt and Hannon, 2002; Murphy and Lehnhausen, 1998; Steeger and Dulisse, 1997). One of the common characteristics of burns and large-scale beetle kills is that both types of disturbance tend to break up the continuity of the living forest into isolated though clustered patches. And several species of woodpecker seek the "remnant patches" for their inherent old forest features to build nest (and roost) cavities.

Deterrent strategies

Replacement of wooden poles with engineered poles (steel, laminated wood, concrete and fibreglass poles) has been documented as a successful deterrent to woodpeckers throughout North America. Several factors, ranging from engineering to installation considerations, cost of the material, overall weight and transportation logistics will be the primary determinants of suitability for a 230 kV pole structure. Among these different types of poles, laminated wood poles most closely approximate the standard wooden pole in terms of weight, cost and ease of installation. While alternative materials to wooden poles offer an obvious solution to long-standing issues with woodpeckers, such poles are generally more expensive than wood and placement of heavier poles is cumbersome in rugged terrain. In the end, far too many pole replacements could be made where the surrounding landscape has changed and woodpecker issues have long subsided.

Other cost-effective strategies have proven effective but with greater facility to resolve woodpecker issues in situ and to be relocated as new problem areas arise. Myrica Systems Inc. in Manitoba experimented with the use of territorial acoustic stimuli in pileated woodpeckers as a deterrent to both excavating and foraging activities on power poles (McIlraith and Berger, 2000). DC Enterprises Inc. has patented another type of noise deflector based on infrared detection of warm-blooded animals. The device emits a sharp sound intermittently at 120 decibels when a warm-blooded animal (e.g., bird or mammal) moves through the detection field. The detection range can be adjusted so that only the upper part of the power pole will trigger the noise. These units will be tested experimentally in 2004 and 2005 to ascertain how well they work on transmission line 2L352.

Retention of damaged poles along rights-of-way

Damaged poles could be relocated along the edge of the right-of-way in conjunction with the aforementioned deterrent strategies. The repositioning of damaged poles serves to test whether the woodpeckers are inclined to continue to use cedar poles albeit in a different location. This could provide further evidence of the functional purpose of cavities in power poles in general, and it may mitigate the inclination to excavate new cavities further down the line. In many cases there are suitable natural substrates adjacent to the line, some with cavities present, which might be monitored for roosting or excavating activity after acoustic deterrents have been mounted on right-of-way poles. Dennis (1964) conjectures that relocating poles will result in disuse since woodpeckers are more interested in the precise location of the pole rather than its presumed utility as a roosting site, especially if its location is perceived to be advantageous for predator or competitor surveillance. There is not much empirical data, however, to refute or support this point.

Other issues in respect to woodpecker damage to utility poles

Habitat context of landscapes surrounding power rights-of-way is a critical part of the damage issue. Some situations require special attention. For example, recent burns act as source habitats for woodpeckers and other bird species that seek the rich abundance of insects that ensues for 2–3 years after a wildfire (Murphy and Lehnhausen, 1998; Hoyt and Hannon, 2002). Large wildfires occur frequently in British Columbia. In 2003 two separate fires north of Kamloops within the North Thompson transmission region consumed 10 and 16 km of line causing extensive power outages across the eastern region. Dennis (1964) asserts that newly established transmission lines and recently placed power poles (including replacement of damaged poles) invite cavity excavation by certain species of woodpeckers. The significance of these burns to woodpecker distribution patterns and the likelihood of damage to the newly placed power poles should therefore be considered during the ensuing 3 years after fire. All woodpecker species are known to select recent burns as a preferential place to forage and nest, where they take advantage of the rich though short-term availability of insects in these areas.

Provincially, the southern interior areas of the province are much more prone to attack than northern and coastal regions. Some of the woodpeckers in the southern interior are listed as rare or endangered throughout Canada. Three of the 12 species of woodpeckers that occur in British Columbia are blue- or red-listed (Lewis's woodpecker, Williamson's sapsucker, white-headed woodpecker), and two of these (Lewis's woodpecker and Williamson's sapsucker) are known to use cavities in power poles (Campbell et al., 1990). These species are found in the dry southern interior of B.C. especially in sensitive ecological zones where sporadic damage of power poles is evident in the transmission database. Many of the transmission lines where we suspect these woodpeckers to occur in the southern interior carry the highest action index in Table 2. It is possible for these birds to have established a dependence upon the power poles as a means of utilizing the surrounding habitat for food, especially in the very open bunchgrass zones where the availability of cavity substrates is limited. Lewis's woodpecker is a weak excavator and is known to usurp cavities, such as those found in power poles, excavated by other woodpecker species (Saab et al., 2004). Hence, cavity usage by Lewis's woodpecker and Williamson's sapsucker in power poles warrants full-fledged investigation on how to deal with these woodpeckers before replacing poles on lines where they occur; otherwise the transmission company could find themselves in contravention of the Species at Risk Act (2002). In addition to these species, a subspecies of hairy woodpecker on the Queen Charlotte Islands is blue-listed. We have no knowledge of whether this species is associated with the power pole damage on the Queen Charlotte Islands where pileated woodpeckers are known to be absent (Taylor, 2002).

Many power companies throughout North America replace poles with woodpecker holes or have installed laminated wood poles or non-wooden poles as a means of mitigating the problem. But some structural engineers are not convinced there is an issue here. In the province of Alberta for example, woodpecker damage to power poles is not an issue because pole breakage due to woodpecker cavities is extremely rare. Recent studies of fungal decay associated with woodpecker activity suggest that woodpeckers act as vectors of fungal transmission by inoculating trees and snags with fungal spores and hyphae (Farris et al., 2004; Jackson and Jackson, 2004). Both foraging activity and cavity excavation play a part in this process. By this means, woodpeckers are an integral part of tree turnover in the forest. These concepts pertain to the process of natural decay of woody substrates within the context of a humid forest, but this may differ greatly for a chemically-treated power pole in an open right-of-way. Hence, more information is needed about the structural integrity of commercial western red cedar poles after they bear woodpecker cavities and the rate of fungal decay of these poles.

CONCLUSIONS

This study of woodpecker damage to wooden transmission poles in British Columbia reveals that damage is largely due to pileated woodpecker based on the large size and shape of the cavity entrance and position of cavities in the upper third of the pole. Most cavity damage is located in the dry southern interior part of the province, notably in biogeoclimatic zones dominated by Douglas-fir. Within a given transmission line cavity damage tends to be aggregated, especially in areas where there is good foraging potential for these woodpeckers. We are inclined to believe that these cavities are used for roosting or predator surveillance, rather than nesting. Mitigation of damage by pileated woodpeckers might be resolved through a combination of strategies that deter woodpeckers away from right-of-way poles and stimulate resumption of activity in displaced poles (bearing roosting cavities) or adoption of natural substrates along the edge of the right-of-way. Further definition of the structural integrity of wooden power poles bearing woodpecker cavities is needed since substrates, such as western red cedar, may not be prone to pole failure or rapid decay by fungi.

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REFERENCES

Aitken, K.E.H. 2002. Nest site availability, selection and re-use in a cavity nesting community in forests of interior British Columbia. Thesis. University of British Columbia, BC.

Aitken, K.E.H., K.L. Wiebe, and K. Martin. 2002. Nest-site reuse patterns for a cavity-nesting bird community in interior British Columbia. Auk, 119: 391–402.

Aubry, K.B. and C.M. Raley. 2002. Selection of nest and roost trees by pileated woodpeckers in coastal forests of Washington. Journal of Wildlife Management, 66: 392–406.

Bull, E.L. 1987. Ecology of the pileated woodpecker in northeastern Oregon. Journal of Wildlife Management, 51: 472–481.

Bull, E.L. and R.S. Holthausen. 1993. Habitat use and management of pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management, 57: 335–345.

Bull, E.L., R.S. Holthausen, and M.G. Henjum. 1992. Roost trees used by pileated woodpeckers in northeastern Oregon. Journal of Wildlife Management, 56: 786–793.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser, and M.C.E. McNall. 1990. The birds of British Columbia, v. 2. Nonpasserines, diurnal birds of prey through woodpeckers. Royal British Columbia Museum, Environment Canada and Canadian Wildlife Service. 636 pp.

Conner, R.N. 1979. Seasonal changes in woodpecker foraging methods: strategies for winter survival. Pages 95–105 *in* J.G. Dickson, R.N. Conner, R.R. Fleet, J.C. Kroll and J.A. Jackson, editors. The role of insectivorous birds in forest ecosystems. Academic Press, Inc., New York, N.Y.

Crockett, A.B. and P.L. Hansley. 1978. Apparent response of *Picoides* woodpeckers to outbreaks of the pine bark beetle. Western Birds, 9: 67–70.

Dennis, J.V. 1964. Woodpecker damage to utility poles: with special reference to the role of territory and resonance. Bird-banding, 35: 225–253.

Farris, K.L., M.J. Huss, and S. Zack. 2004. The role of foraging woodpeckers in the decomposition of Ponderosa pine snags. Condor, 106: 50–59.

Harestad, A.S. and D.G. Keisker. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. Canadian Journal of Zoology, 67: 1067–1073.

Holt, R.F. and K. Martin. 1997. Landscape modification and patch selection: The demography of two secondary cavity nesters colonizing clearcuts. Auk, 114: 443–455.

Hoyt, J.S. and S.J. Hannon. 2002. Habitat associations of black-backed and three-toed woodpeckers in the boreal forest of Alberta. Canadian Journal of Forest Research, 32: 1881–1888.

Jackson, J.A. and B.J.S. Jackson. 2004. Ecological relationships between fungi and woodpecker cavity sites. Condor, 106: 37–49.

Krebs, C.J. 2001. Ecology: The Experimental Analysis of Distribution and Abundance. 5th ed. Benjamin Cummings, Menlo Park, California. 801 pp.

Martin, K., K.E.H. Aitken, and K.L. Wiebe. 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: Nest characteristics and niche partitioning. Condor, 106: 5–19.

McIlraith, A. and R. Berger. 2000. Prevention of pileated woodpecker (*Dryocopus pileatus*) damage on Manitoba Hydro utility poles. Manitoba Hydro Research and Development Program.

Murphy, E.C. and W.A. Lehnhausen. 1998. Density and foraging ecology of woodpeckers following a stand-replacement fire. Journal of Wildlife Management, 62: 1359–1372.

Parker, K.R. 2003. Mitigation of woodpecker damage to power poles on transmission line 2L352 in the Cariboo Region of British Columbia: Preliminary findings for June–October 2002. BC Hydro.

Parker, K.R. 2004. System-wide assessment and proposed mitigation of woodpecker damage to transmission poles in British Columbia: Findings and recommendations from the 2003 field season. BC Transmission Corporation & BC Hydro.

Saab, V.A., J. Dudley, and W.L. Thompson. 2004. Factors influencing occupancy of nest cavities in recently burned forests. Condor, 106: 20–36.

Species at Risk Act. 2002. Chapter 29, Bill C-5. Royal Assent, December 12, 2002. Consolidated Statutes of Canada, Department of Justice, Government of Canada.

Steeger, C. and J. Dulisse. 1997. Ecological interrelationships of three-toed woodpeckers with bark beetles and pine trees. B.C. Min. For., Victoria, B.C. Ext. Note 035.

System Transmission Asset Recording and Reporting (STARR). 2003. Ongoing database for transmission line inspections and maintenance work of the integrated power grid of British Columbia. Microsoft Excel with linkage to EGIS GIS system. British Columbia Transmission Corporation.

Taylor, P.A. 2001. A study of woodpeckers in BC Hydro's Northern Interior Region. BC Hydro.

Taylor, P.A. 2002. A study of woodpeckers in BC Hydro's Non-integrated Region. BC Hydro.

Warren, T.L., M.G. Betts, A.W. Diamond, and G.J. Forbes. 2005. The influence of local habitat and landscape composition on cavity-nesting birds in a forested mosaic. Forest Ecology and Management, 214: 331–343.

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Monk Parakeets: An Expanding Problem on Power Lines and Other Electrical Utility Structures

J.R. Newman, C.M. Newman, J.R. Lindsay, B. Merchant, M.L. Avery, and S. Pruett-Jones

The monk parakeet (*Myiopsitta monachus*), a bird native to South America, was brought to the US in the late 1960s and early 1970s as a pet. They have escaped and now populations breed throughout the US from Florida to New York to Oregon to Texas. In urban and suburban areas in Florida and other states the monk parakeet nests on transmission lines, substations and distribution poles as well as other man-made structures and trees. As a stick building nester, its populations have grown exponentially in the last 10 to 15 years. Their nests on utility structures cause significant electrical reliability problems, increased operation and maintenance costs, and safety concerns. The monk parakeet is an invasive species that is banned in some states, e.g. California, but not in others, e.g. Florida. In the past, control of the monk parakeet involved shooting the birds. This was socially unacceptable and control measures stopped. Presently the most effective short-term control strategy is capture of the birds and removal of the nest. Nest removal without capture of the birds only compounds the problem, as the parakeets will rebuild their nests. Long-term controls for the monk parakeet are not yet developed, however, a chemosterilant, Diazacon, shows promise. This paper describes the effects of monk parakeets to electric utilities and other economic sectors, monk parakeet basic biology, and short-term and long-term control and management strategies.

Keywords: Monk parakeet, biology, nesting, electric reliability concerns, safety considerations, operation and maintenance costs, control and management strategies, ROW

INTRODUCTION

The monk parakeet (*Myiopsitta monachus*), a bird native to South America, was brought to the US in the late 1960s and early 1970s as a pet. It escaped and has become naturalized. Monk parakeets have spread and now populations breed throughout the United States. Their populations have grown exponentially. Monk parakeets have adapted to the urban and suburban environment and nest not only in trees but on man-made structures including electric utility structures. This nesting is causing electrical reliability and safety problems. Presently there is no known effective way to control monk parakeets. This paper describes the effects of monk parakeets to electric utilities and short-term and long-term control and management strategies and is based on research studies conducted by Florida Power & Light Company (FPL) from 2001 to 2004.

BIOLOGY OF THE MONK PARAKEET

Basic biology

The monk parakeet is a medium sized parrot (11 to 13 inches or 28 to 33 cm) native to South America. It occurs naturally from central Bolivia and southern Brazil south to central Argentina. Adult males are slightly larger than females and both have identical in plumage. They are a grey/green bird with green

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plumage on the back and tail, and grayish in coloration on the underside. The wings are dull green with the outer wing feathers blue. The tail is long and graduated and the bill is thick and yellowish brown with a brownish tip. Juveniles resemble adults with the exception that the feathers on the forehead of juveniles are darker (slate gray) than that of adults (gray-white) (Spreyer and Bucher, 1998). Monk parakeets feed on seeds and fruits. Analyses of food items from birds captured in South Florida indicate that at least 75% of the food items are seeds from bird feeders.

The species has been introduced and became established as a naturalized species to the mainland of the United States, Puerto Rico, Bahamas, West Indies, England, Belgium, Italy, Spain, and the Canary Islands. Monk parakeets have been introduced into at least 18 states: Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Massachusetts, Nebraska, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, and Washington, D.C./Virginia. The largest populations are in Florida, Illinois, New York, Rhode Island, and Texas (Spreyer and Bucher, 1998). The continuing presence of parakeets in the Northeast (e.g. New York City and New Haven) and the Midwest (e.g. Chicago) demonstrates their ability to survive cold, seemingly inhospitable winter conditions. In Chicago, parakeets in the winter fed almost exclusively on seeds from bird feeders (Hyman and Pruett-Jones, 1995). The ability of the monk parakeet to survive harsh winters is no doubt facilitated by food provided by people at bird feeders and other sites.

The species became established in the United States during the 1960s because of accidental or purposeful releases by individuals or pet shops. Thousands of monk parakeets were and have been imported for the pet trade. In the four-year period from 1968 to 1972, 64,225 monk parakeets were imported into the United States for the pet trade (Spreyer and Bucher, 1998). Because of the possibility that it would become an agricultural pest species, the Monk Parakeet was the focus of an eradication program by the United States Fish and Wildlife Service (USFWS) in the 1970s. This program reduced the numbers of monk parakeets at that time by approximately one-half (Neidermyer and Hickey, 1977). Since 1975, the year that the USFWS removal program ended, the numbers of Monk Parakeets have recovered and the species has exhibited a dramatic population expansion to levels far above the pre-control numbers in the early 1970s (Van Bael and Pruett-Jones, 1996; Pruett-Jones and Tarvin, 1998) (Fig. 1). Monk parakeets have exhibited a similar population expansion and increase in Europe, where it is also a naturalized species (Sol et al., 1997). In Florida, the largest numbers of parakeets are in the south and west coast of Florida where populations greatly expanded in the 1990's (Fig. 1).

Monk parakeets are the only species of parrot to build their own nest of sticks, they exhibits cooperative breeding, and are colonial breeders (more than one pair may occupy a nest structure, up to 20 pairs have been observed in some nest structures) (Sol et al., 1997; Eberhard, 1998; Spreyer and Bucher, 1998). The nests can range in size from a couple feed in diameter up to ten or more feet in diameter. Monk parakeets build nests on tall structures including trees and man-made structures. Surveys in South Florida show that in some locations 80% of the nests occur on man-made structures (Table 1).

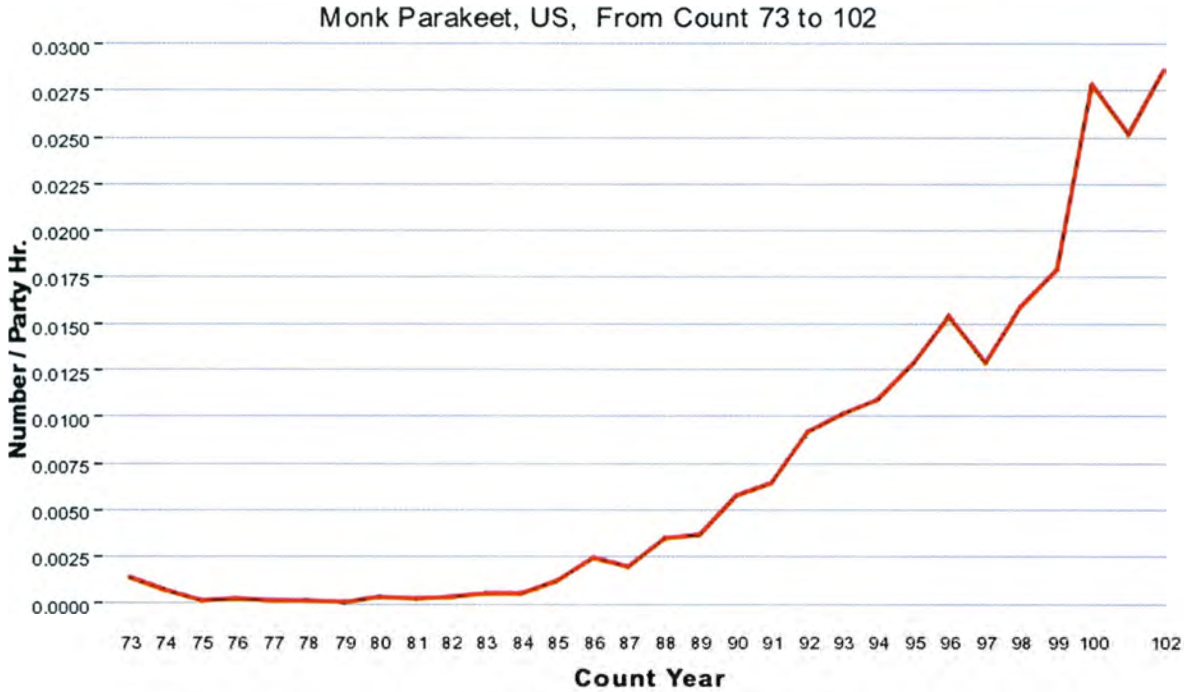
Monk parakeets have been observed nesting on crevices in buildings and window air conditioners in Brooklyn, New York. An examination of land use/land cover relationships in South Florida shows that monk parakeets, whether nesting on trees or man-made structures, nest primarily in residential areas (high and low) and appear to prefer these areas over areas dominated by natural vegetation and agriculture. Similar patterns are seen in New York, Connecticut, Illinois and Texas.

One misconception is that the monk parakeet is related to the Carolina parakeet (Conuroposis carolinensis), which became extinct in the US in the early 1920s. Monk parakeets are not closely related taxonomically nor do they fill the same niche as the Carolina parakeet. Carolina parakeets were wetland forest dwelling species that primarily build nests in trees.

Nesting characteristics on electric utility structures

From a utility perspective the population growth of monk parakeets on utility structures has two characteristics, an increase in the number of nests on a structure, and an expansion of nesting to different structures. In the South Florida study there was a 23% increase in nesting within substations with nests (351 to 430 nests) from 2001 to 2002 and a 13% increase in nesting on new substations (38 to 43 substations). For transmission lines, there was a 55% increase in nests on towers with nests (309 to 478) and 54% expansion of nests on new towers (218 to 335 towers).

The location of monk parakeet nests on distribution poles is quite predictable in South Florida. Eighty-two percent of the nests occurred on poles with transformers and capacitor banks. In particular, they appear to prefer building their nests on the brackets that attach the transformers and capacitor banks to the poles. In substations, 44% of the nesting occurred on 45° angle cross beams, followed by switches (18%) and vertical supports (18%). Other locations were also used including primary 90O supports, insulator/switches, and other substation support structures. Out of 54 towers surveyed, 96% of the nesting occurred on the secondary arms of the tower followed by the primary arms (69%). The one common situation in both substations and transmission lines is their apparent preference for 45° angles. On transmission towers, 93% of the nesting locations were in 45° angle braces. The cross arms ends with these angles were most frequently used (74%).



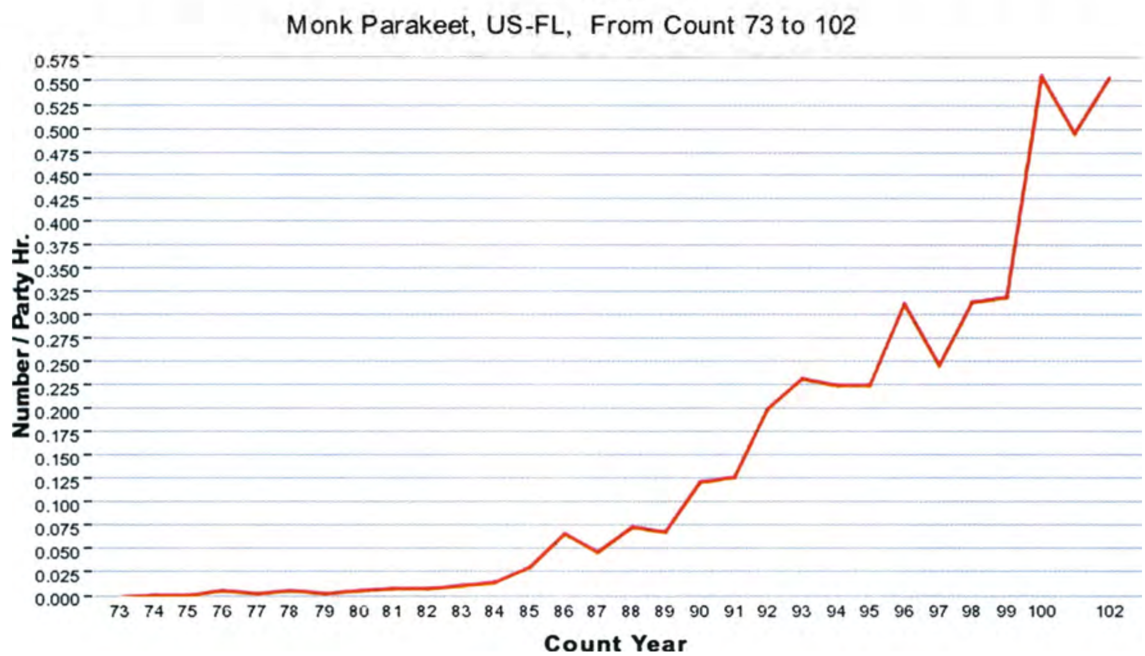


Fig. 1. Population growth of the monk parakeet from 1973 to 2002 (Count Year 73 to 102) in the US and Florida since 1973 (based on Christmas Bird Count Data).

Table 1. Nesting locations of monk parakeets in South Florida based on 60 transects

Distribution Poles	Substations	Transmission Lines	Stadium Lights	Satellite Towers	Radio Antennas	Light Poles	Trees
52% (81)	<1% (1)	7% (11)	9% (14)	1% (2)	3% (4)	8% (12)	20% (31)

EFFECTS OF MONK PARAKEETS

Monk parakeets cause significant problems to electric utilities and other sectors because of their feeding and nesting behaviors.

Effects to electric utilities

The major effect of monk parakeets to electric utilities is from their nest building behavior. Monk parakeets build a bulky nest structure of sticks and branches not only on trees but also in substations and on distribu-

Fig. 2. Nesting of monk parakeet on electric utility structures.

tion poles and transmission towers (Fig. 2). These nests can cause outages and fires.

The birds' tendency to use electric utility facilities occurs both in the parakeet's native range in South America (Bucher and Martin, 1987) and in the United States (e.g. Simpson and Ruiz, 1974; van Doorn, 1997). Monk parakeet nests can cause decrease in electric reliability, equipment damage, lost revenue from nest and bird caused power outages, increase in operation and maintenance costs associated with nest removal and repair of damaged structures, and pubic safety concerns. Monk nests attract predators (including humans) that also can cause outages. Problems with nesting on utility structures have been reported in Colorado, Connecticut, Florida, New York, New Jersey, Rhode Island and Texas. The problem of monk parakeets nesting on electric utility facilities in Florida dates back to at least to the late 1980's. Nesting activity has become an important service reliability issue more recently as the population has expanded (Avery et al., 2002).

Electrical reliability concerns

Effects to electrical reliability are the most significant problems with monk parakeets nesting on utility structures. For example, for a five-month period in 2001 a total of 198 outages related to monk parakeets were logged and affected over 10,000 customers in two counties in South Florida. The frequency of outages increases during wet weather. These outages result from nesting material completing an electric circuit between two energized parts or an energized part and a grounded part of electrical equipment. In some cases the nests get too large and complete an electric circuit. In other cases individual monks can bring nesting materials that can result in completing a circuit. Fires can start in the nesting material causing damage to transformers and other utility equipment.

Safety considerations

Safety concerns have included loss of power to critical care facilities, risk of injury to maintenance crews, and increased incentives to and risks of trespassing. In some service areas, e.g. New York City, distribution poles with lines connecting to residences have signs indicating that the resident is on some type of life support system requiring continuous power. Nests on these poles or nearby distribution feeders pose a significant risk to these residents. Crews taking down nests are also at increased risk of injury. Although monk parakeets do not appear to be vectors for any human diseases the crews need to be protected from nest materials that contain mites and other insects that can cause itching and discomfort. Finally, because of the trade in monk parakeets in the pet industry, it is common for people to personally trap monk parakeets and to sell them to pet shops and other individuals. Wild caught monk parakeets can be sold to pet owners for as much as $150 per bird. A number of electrocutions have occurred to individuals who have trespassed and climbed into substations to trap monk parakeets.

Operation and maintenance costs

There are several operation and maintenance costs associated with the effects of monk parakeets including direct costs such as:

1. Lost electric power sales revenue during outages.
2. Costs for restoration of power outages and repair of equipment damaged during outages.
3. Costs for removal of nests and other control and mitigation measures.
4. Indirect costs for utility management time and effort in attending to the problem.
5. Costs to electric customers for loss of service or reduced electrical system reliability.

These costs can be quite considerable. For example, for the five-month period in 2001 when 198 outages related to monk parakeets were logged, lost revenue from electric power sales was $24,000. The cost for repair of outages was much more significant cost, estimated to be $221,000 for 2001. The combined total estimated costs for 2001 associated with the outages were $245,000 for only a portion of the FPL Service Area.

Effects to other industries

In South America, monk parakeets are reported to cause an estimated 2 to 45 percent loss on agricultural and orchard crops. In 2003 there was a report of monk parakeets causing significant damage to the tomato crop in Spain (BBC News, Thursday, 28 August, 2003, Quaker Parrots Invade Barcelona, by Danny Wood). In the 1970's the U.S. Department of Agriculture predicted that if monk parakeets became abundant in the US they would cause serious damage to agricultural and orchard crops. (Buhler et al., 2001). To date the monk parakeet has not spread in significant numbers to agricultural areas. No widespread commercial agriculture damage has been reported. Some damage to backyard homeowner fruit trees was reported. Connecticut has had sporadic reports of minor damage to backyard gardens and ornamental trees (Pearson and Olivieri, 1995). In South Florida, parakeets are known to feed on cultivated tropical fruits, such as longans (Tillman et al., 2001; Fig. 3). Based on the known feeding habits of monk parakeets in their native South American range (Spreyer and Bucher, 1998), many other crops in Florida such as sweet corn, rice, and blueberries are potentially susceptible to damage by this species. In addition to eating fruit itself, parakeets also consume buds and flowers, which exacerbate their potential impact on crops.

There is also the possibility that parakeets will disseminate plant disease agents injurious to other crops in particular citrus crops. For example, in Florida citrus canker is a major concern. Monk parakeets build nests with sticks from various trees (Spreyer and Bucher, 1998). If parakeets happen to select an infected citrus tree for nest material, then the disease could be spread to uninfected areas, making control efforts more difficult. To date, serious agricultural damage has not materialized in Florida because monk parakeet populations are primarily found in urban and suburban areas; however, recent surveys of monk parakeets nesting on transmission lines in South Florida have found them extending their nesting into agricultural areas.

Where monk parakeet populations occur they are commonly found nesting on communication towers structures including cell towers, TV towers, and radar towers (Fig. 4). Although their nests can be quite large, their effects to communication are not known. The nests appear to be a nuisance with bird droppings or blocking access to upper reaches of towers. Presently they are seen as a maintenance problem. No effects to communication have been reported based on discussions with several communication tower owners who had nests on their towers.

CONTROL AND MANAGEMENT

Goals and objectives

The short-term and long-term goals for controlling and managing monk parakeet nesting are:

1. Reduce or eliminate electric reliability problems.
2. Reduce system operation and maintenance costs.
3. Reduce or eliminate public safety problems.

Since monk parakeet populations create reliability problems, increase costs and safety concerns, and are expanding exponentially in some locations, there is a need for both short-term and long-term control and management objectives. The short-term objectives are to remove high-risk nests and prevent nesting on structures. The long-term objectives are to reduce population size, reduce population growth, and enact legislation and policies to control monk parakeets.

Strategies

Strategies for achieving the short-term objectives need to be different for distribution poles, substations, and transmission lines because of structural differences of these systems and locational differences of the nests on the systems. Table 2 presents a summary of different short-term strategies that have been evaluated and tested by FPL.

Fig. 3. Monk parakeets feeding on Logan fruit in South Florida.

Fig. 4. Nesting of monk parakeets on communication equipment.

Table 2. Examples of various short-term strategies investigated for control and managing monk parakeet nesting on electric utility structures

General strategy	Specific strategy	Comments on effectiveness
Nest Removal with Captures of Birds	Manually take down the nest and capture of birds with net	Effective for distribution poles Is only effective if monk parakeets in the nests are also trapped, since renesting will occur Recolonization occurs but is the slowest if all birds are captured prior to taking down the nest Labor intensive and requires public education and cooperation Different trapping techniques needed for distribution poles versus substations Not practical for transmission towers
	Mechanically remove the nest	Nest can be removed by water canon or other device but not effective because of recolonization and public concern May be effective if repeated when new nests are started
Physical Deterrents	Structural modification of preferred nesting locations on structures, e.g. cover for transformer attachments	Different covers have been tried but the "seal" between pole and equipment needs to be very small so that nesting materials cannot be inserted
Behavioral Deterrents	Scare devices, e.g. laser	Temporary disruption of birds, but over a period of time (e.g. hours or days) birds return to previous nesting levels
	Effigies	No effect
	Electrical shock	Impractical because of engineering safety considerations
	Chemical Repellants, e.g. ReJex-iT	Not effective, temporary disruption, but birds adapt including building nests in different locations within a matter of days
Chemical Control	Various EPA-approved toxicants	Not feasible because of potential non-target species effects and public acceptance issues
Reproductive Control	Chemosterilants such as Diazacon	Potentially effective in reducing egg laying, field testing necessary. If proven effective public education necessary
ROW Management	Habitat Management	Not effective, monk parakeets appear to show nesting preferences based on surrounding land use not on ROW conditions

Only nest removal coupled with the capture of the birds shows promise in reducing high-risk nests and preventing renesting. Active trapping of monk parakeets with a net is required for distribution poles. Birds are first removed from the nests at night and then the nests are removed. If nests are removed without trapping the birds, the birds will renest. If the original nest was a colony of more than one pair it is very likely that each of these displaced pairs will build their own nests on the same or nearby structure. Passive trapping with a cage is somewhat effective for substations.

Long-term strategies include approaches to reduce the population size, to contain or reduce the nesting area, and reduce population growth so that the monk parakeet population diminishes over time. A number of long-term strategies exist including identifying some type of natural biological control. One such potential natural biological control is the protozoan (*Sarcocystis falcatula*), considered harmful to other parakeet species but not to other species of birds. However, the monk parakeet was found resistant to *Sarcocystis falcatula*. Lethal control, such as shooting, was somewhat successful in the early 1970s but was not considered socially acceptable and was discontinued. Other lethal control alternatives include chemical control. For example, DRC-1339 (Starlicide®) is an EPA-approved toxicant used to control starlings and other problem bird species, but the efficacy on monk parakeets is not established. Pubic acceptance of such a control measure would be more difficult than other forms of control. Reproductive control is another long-term strategy whereby the population growth on utility structures might be slowed. Primary information suggests that monk parakeet offspring may show a preference for nesting on the same substrate as their parents. If this is the case then selective reproductive control of these populations would be possible. Diazacon, a chemosterilant formerly registered as Ornitrol® to prevent egg formation for pigeons, is a potentially useful reproductive control chemical. This approach, if found to be effective, would likely have broader public support than direct lethal control. Initial feeding trial with monk parakeets indicates that Diazacon may have similar affects on monk parakeets. Further feeding studies and field studies are warranted.

It is important to enact legislation and policies on the owning and selling of monk parakeet. Currently, no national policy exists for management or control of the monk parakeet. The original Lacey Act of 1900 attempted to control the importation of exotic species but included an exemption for monk parakeets. A number of states have legislation that prohibits the importation, transportation, or possession of monk parakeets. These states include California, Connecticut, Hawaii, Kansas, Kentucky, Pennsylvania, Rhode Island, Tennessee, and Wyoming where it is also illegal to own or sell monk parakeets. Florida has no restriction. It is important to point out that a number of these states have monk parakeets in spite of the laws, e.g. Connecticut and Rhode Island. Although the laws themselves will not assure that monk parakeets will not occur, they provide a governmental recognition of the invasive nature of monk parakeets and are more likely to provide electrical utility companies with government support for proposed control of the monk parakeet.

CONCLUSIONS AND RECOMMENDATIONS

Monk parakeets are an invasive species found throughout US. Their populations are expanding. Escaped pets have adapted to nesting on electric utility facilities and other man-made structures. Although the effects vary from place to place, monk parakeet nesting is a significant and growing problem for the electric utility industry. The nests of monk parakeets cause electrical reliability problems, increased operation and maintenance costs, and increased public safety considerations. Because of the differences in utility structures and differences in monk parakeet nesting patterns on the structure, different control strategies are required for different systems.

Management and control of the monk parakeet need to include the short-term objectives of removing high-risk nests and preventing nesting on structures. Long-term objectives need to include reducing population growth and population size, and enacting legislation and policies to control monk parakeet. Currently, trapping birds combined with nest removal is the only viable short-term strategy for distribution poles and substations. This strategy is labor intensive and has public acceptance issues. Trapping and removal, if repeated, may be effective in a long-term strategy of reducing populations, but is labor intensive and needs to be repeated at least annually until the nesting stops. Presently, one potentially useful long-term strategy for reducing populations and population growth is a type of reproductive control. Continued research on this Diazacon is needed to make it practical and effective. Since monk parakeet nesting is an industry-wide problem cooperative research is needed.

A concerted effort is also needed by the utility industry to obtain invasive species policy support for the monk parakeet and enforcement where none exists. This effort needs to be coupled with education of public and natural resources agencies on the importance of the problem.

REFERENCES

Avery, M.L., E.C. Greiner, J.R. Lindsay, J.R. Newman, and S. Pruett-Jones. 2002. Monk parakeet management at electric utility facilities in south Florida. Vertebr. Pest Conf., 20: 140–145.

Bucher, E.H. and L.F. Martin. 1987. Los nidos de cotorras (*Myiopsitta monachus*) como causa de problemas en lineas de transmision electrica. Vida Silvestre Neotropical, 1: 50–51.

Buhler, R.D., J.D. Lambley, and T. Sim IV. 2001. Pest Risk Analysis, Monk Parakeet, *Myipsitta monachus*. Kansas Department of Agriculture, Plant Protection and Weed Control, Topeka, Kansas. Digest, 17(2): 56.

Eberhard, J.R. 1998. Breeding biology of the Monk Parakeet. Wilson Bulletin, 110: 463–473.

Hyman, J. and S. Pruett-Jones. 1995. Natural history of the monk parakeet in Hyde Park, Chicago. Wilson Bulletin, 107: 510–517.

Neidermyer, W.J. and J.J. Hickey. 1977. The Monk Parakeet in the United States, 1970–1975. American Birds, 31: 273–278.

Pearson, L. and A. Olivieri. 1995. Monk Parakeets: Why Here? Bird Watcher's Digest, 17(2): 56.

Pruett-Jones, S. and K.A. Tarvin. 1998. Monk Parakeets in the United States: Population growth and regional patterns of distribution. Pages 55–58 *in* Proceedings 18th Vertebrate Pest Conference (R.O. Baker and A.C. Crabb eds.), University of California, Davis.

Simpson, M.B. and R.C. Ruiz. 1974. Monk parakeets breeding in Buncombe County, North Carolina. Wilson Bull., 86: 171–172.

Sol, D., D.M. Santos, E. Feria, and J. Clavell. 1997. Habitat selection by the Monk Parakeet *Myiopsitta monachus* during the colonization of a new area. Condor, 99: 39–46.

Spreyer, M.F. and E.H. Bucher. 1998. Monk Parakeet (*Myiopsitta monachus*). In A. Poole and F. Gill (eds.), The Birds of North America, No. 322. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Tillman, E.A., A. van Doorn, and M.L. Avery. 2001. Bird damage to tropical fruit in south Florida. Eastern Wildlife Damage Management Conference, 9: 47–59.

Van Bael, S. and S. Pruett-Jones. 1996. Exponential population growth of Monk Parakeet in the United States. Wilson Bulletin, 108: 584–588.

van Doorn, A. 1997. Factors influencing success and population trends of introduced parrots in Florida. MS Thesis, University of Florida. 76 pp.

BIOGRAPHICAL SKETCHES

The authors have been conducting research on the behavior, ecology, management and control of monk parakeets since 2000. Each of the authors has been evaluation bird interactions with power lines for more than 10 years. This research has been sponsored by Florida Power and Light Company.

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Assessment of Damage on Electric Transmission Wood Poles Caused by Pileated Woodpecker (*Dryocopus pileatus*)

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Many electric utilities report heavy damage by woodpeckers on wood poles. In 2001, TransÉnergie initiated a long-term field study on 2 twin-pole 120 kV transmission power lines; one located in the hardwood forest, and the other in the southern boreal forest. The goal of the study is twofold: 1) to understand the ecological aspects of the problem, and 2) to elaborate solutions to reduce the damage. This paper focuses on the first two years (2001 and 2002) of the project and presents data on damage intensity and distribution, pole utilization by woodpeckers and it discusses variables associated with damaged poles. On both lines, a total of 354 individual poles were examined. The number of poles with woodpecker damage was 94 (42.9%) for the boreal site, while it was 39 (28.9%) for the line in the hardwood forest. The most severe damage was from nesting or roosting cavities and most of them were excavated by Pileated woodpecker (*Dryocopus pileatus*). The average height of 133 nesting/roosting orifices made by Pileated woodpeckers (PW) on poles was 8.7 m. Including the new openings found in 2001 and 2002, the mean number of openings/year since line construction was 5.7 in the boreal forest and 1.2 in the hardwood forest, in the segments studied. PW selected poles with the largest diameter at breast height values for excavating a nesting cavity. The large number of poles damaged over the years, suggests that pole diameter is generally larger than that of most trees in the surrounding forest. Results indicate that PW tend to excavate a new orifice to reach an existing cavity when an old orifice is plugged by maintenance crews.

Keywords: Cavities, damage, DBH, nesting, Pileated Woodpecker, powerline, roosting, wood pole, right-of-way

INTRODUCTION

Damages to utility wood poles have been reported since the 19th century (Sennet, 1879; in Dennis, 1964). Several species of woodpeckers excavate holes in powerline transmission wood poles, sometimes causing considerable damage. This can reduce network reliability, and increase maintenance activities and operating costs. In Quebec, we identified several line segments with significant damage, indicating the importance for developing solutions to reduce this problem. In spring 2001, TransÉnergie initiated a research program to address the Pileated woodpecker (PW) wood pole issue. We selected two transmission lines for the study; one in the boreal forest (circuit 1475 La Vérendrye-Parent), and the other in the hardwood forest (circuit 1100 Maniwaki-Paugan). The ultimate goal of the research program is to develop solutions to reduce or eliminate damages. The objectives for 2001 and 2002 were the following:

1. Describe woodpecker activities (feeding, nesting, drumming), and the scope of pole use;
2. Describe damaged poles (woodpecker cavities);
3. Characterize cavities;
4. Determine variables that explained pole attraction; and
5. Describe the use of cavities by other species.

STUDY AREA

The study was conducted on two 120 kV power lines. Power line number 1475 was built in 1985 to connect

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the La Vérendrye substation to the town of Parent (47°90′N; 74°60′W). The entire line contains 283 H-frame towers and runs in a north-south axis over a distance of 58 km in a Balsam fir (*Abies balsamea*) and White Birch (*Betula papyrifera*) forest. Line 1475 is located in a forested region where timber harvesting is a dominant activity. Line number 1100 runs between the Paugan and Maniwaki substations (46°40′N; 76°00′W) in the Laurentians. It was built in 1970 and contains 327 H-frame towers over a distance of 70 km in a Balsam Fir and Yellow Birch (*Betula alleghaniensis*) mixed forest, in a partly forested valley, where agriculture is very present in some areas. Poles from both lines were treated with creosote and both rights-of-way measured approximately 30 m in width.

METHODS

Observations about all woodpeckers seen or heard in the rights-of-way included species, sex, and behaviour (calling, drumming, occupying a pole cavity, flight). For each pole examined, we measured diameter at breast height (DBH) with a vernier, number of cracks, percentage of creosote (visual), ant abundance in 4 classes (no ant = 0, present in small number = 1, moderate number = 2, large number = 3), number of woodpecker orifices, number of small holes and estimated number of nesting/roosting cavities. For safety reasons, we could not climb the poles. All observations were made from the ground. For every orifice (hole that seemed to lead to a cavity), we identified the species which excavated the hole, the species that used the hole, year of excavation (2001, 2002 or before), accessibility to the orifice (filled or not), height (m) of cavity above the ground, and exposure. A single cavity was assumed when two holes were less than 50 cm apart. We compared pole DBH, percentage of creosote, number of cracks between poles with PW orifices and poles without PW orifices with Student t tests when conditions were respected or non parametric tests when they were not respected. DBH was compared between poles with one PW orifice and poles with more than one PW orifice using the same tests. Field work took place between May 18 and 30 in 2001 and between 8 and 13 May in 2002.

RESULTS

A total of 165 H-frame towers, including 354 wood poles were examined for woodpecker damage (Table 1). Each tower was made up of 2 or 3 single poles. Many poles have been replaced since the construction of the lines, but the number of those replaced due to woodpecker damage was not determined. Poles on both lines studied were western cedars (*Thuja plicata*). The average DBH of poles was significantly higher ($P = 0.008$) for circuit 1475 (mean DBH = 40.4 cm; range = 27.4–51.6 cm; $n = 219$ poles) than for circuit 1100 (mean DBH = 39.1 cm; range = 32.2–53.5 cm; $n = 135$ poles). But the difference was small.

A large number of poles showed woodpecker damage on the segments of lines studied (Table 2). The proportion was higher on circuit 1475 than on circuit 1100.

Assessment of damage from the ground, with binoculars, enabled us to distinguish two types of woodpecker holes. One type appeared to lead to a nesting/roosting cavity, while the others were less deep, narrower and lead nowhere (Table 3). The existence of a cavity could not be established for the first type of holes because it was impossible to climb the poles for safety reasons. Henceforth, holes which appeared to lead to a nesting cavity, will be called orifices.

A total of 112 woodpecker nesting orifices were observed in the studied segments of line 1475 and 45 on those of line 1100. Most (84.7%) were excavated by Pileated Woodpecker (Table 3). Those done by smaller woodpeckers seemed to be excavated by Yellow-bellied Sapsucker (*Sphyrapicus varius*). The small holes, were also excavated by PW. They represented the majority of holes. The ratio of the number of these small holes and orifices was 2.4 for circuit 1475 and 1.9 for circuit 1100.

Average height of PW orifices was 8.7 m (SD = 2.8 m; range = 1.4 m–19.2 m; $n = 133$) on both circuits.

Table 1. Characteristics of the 2 lines studied

Line	Year of construction	Number of towers studied	Number of segments studied	Number of poles studied	Number of poles replaced since construction
1475	1985	103	2	219	unknown
1100	1970	62	6	135	24 (2001)

Table 2. Distribution of damage to wood poles caused by woodpeckers on the study segments of lines 1475 and 1100 in May 2001

Line	Number of H towers with woodpecker damage	% of H towers with damage	Number of poles with woodpecker damage	% de poles with damage
1475	67	65.0	94	42.9
1100	30	48.4	39	28.9

Table 3. Identification of woodpeckers and damage types on lines 1475 and 1100

Line	Number of orifices			Small holes
	Pileated	Flicker	Small woodpeckers	Pileated
1475	95	6	11	232
1100	38	1	6	71
Total	133	7	17	303

Table 4. Distribution of PW nesting/roosting orifices on studied segments of circuits 1475 and 1100 in May 2001

Line	Number of PW orifices/pole				Pole with PW orifice	
	Mean	SD	Maximum	Minimum	Number	%
1475	0.43	1.7	16	0	28	12.8
1100	0.28	0.7	4	0	24	17.8

PW orifices were significantly higher on poles on line 1475 than on line 1100 ($t = 4.57$; df $= 131$, $P < 0.001$; 9.3 and 7.0 m). On circuit 1475, on average, there was 0.43 PW orifice per pole (SD = 1.7; range = 0–16). Orifices were found on 28 (12.8%) poles. On circuit 1100, on average, there was 0.28 PW orifice per pole (SD = 0.72; range = 0–4). Orifices were found on 23 (17.0%) poles of this circuit (Table 4).

The percentage of poles with at least one PW orifice was not different between the two lines ($X^2 = 1.66$; df = 1; $P = 0.197$; Table 4). The number of orifices per pole varied greatly, especially on line 1475 (Table 4).

Assuming that all PW orifices less than 50 cm apart lead to the same nesting/roosting cavity, their number was evaluated at 56 on circuit 1475; an average of 0.26/pole (SD = 0.83; range = 0–6). On circuit 1100, their number was 32, with a mean of 0.24 nesting/roosting cavity/pole (SD = 0.56; range = 0–3). Possibly, on average, there could be 1.7 orifice/cavity on circuit 1475 and 1.2 on circuit 1100.

In 2001, three new PW orifices were excavated in the poles on the studied segments in both circuits. Two of these orifices were used for nesting. In 2002, two new PW orifices were identified on both lines. Woodpecker damage was noted on circuit 1475 as early as 1989. On that circuit, most poles (29/33) with orifices (all species), had been noted as damaged by woodpeckers, including 28 before 1997. On circuit 1100, orifices were noted as early as 1990 and 18 poles of 23 were already damaged in 1997. Assuming that PW started to excavate orifices as soon as the poles were planted, then, on average 5.7 orifices were excavated annually on circuit 1475 and 1.2 on circuit 1100.

In 2001, on circuit 1475, 59 (62.1%) of PW nesting orifices had been sealed by maintenance workers, on average, 0.27 orifice/pole (SD = 1.1; range = 0–9). Corresponding values on circuit 1100 were 31 (81.6%) for an average of 0.23 orifice/pole (SD = 0.60; range = 0–3). Sealed orifices were observed on 20 poles of circuit 1475 and 21 of circuit 1100.

The mean number of PW orifice per pole was significantly higher in poles with at least one sealed orifice than those without sealed orifice on circuit 1475 ($P = 0.005$; 1.4 and 4.2 orifices; $n = 8$ and 20) but not for circuit 1100 ($P = 0.96$; 1.7 and 1.6 orifices; $n = 3$ and $n = 21$).

The Spearman rank correlation coefficient between the total number of PW orifices per pole and those that are sealed was 0.85 on circuit 1475 ($P < 0.001$) and 0.89 on circuit 1100 ($P < 0.001$). These indicate that PW tend to excavate a new orifice, to reach the existing cavity, when old ones are plugged.

Pileated Woodpecker and Yellow shafted Flicker (Colaptes auratus) were the most frequently observed species in the rights-of-way and adjacent forest. Most birds were observed in the forest. The flicker is the most abundant woodpecker species observed in the rights-of-way and fed on the ground. Few woodpeckers were actually observed on poles; they were mostly individuals nesting in cavities, which they had excavated on poles. In 2001, only a single C. auratus cavity was occupied by this species. Conductors and ground wires were used by American Kestrel (Falco sparverius) as perches to hunt.

In 2001, two orifices were used by PW for nesting, one on each circuit. Others must have been used at least occasionally by PW for roosting. At least three other species used PW orifices: American Kestrel, Common Goldeneye (Bucephala clangula) and a species of wasp. American Kestrel used one PW orifice on line 1475, but observations indicate that it is possible that two other PW orifices were used by this species for reproduction on both lines. The presence of paper sticking out of an orifice leads us to believe that a Red squirrel (Tamiasciurus hudsonicus) used it. Finally, some down at the entrance of another orifice indicated that it was occupied by a bird (species undetermined). In 2002, a Common Goldeneye was nesting in an orifice excavated in 2001 on line 1475. Two orifices were used by PW for nesting in 2002, one on each line.

The DBH of poles with at least one PW orifice was significantly higher to that of poles without a PW orifice for circuit 1475 ($t = -4.61$; df $= 217$, $P < 0.001$; 44.1 (35.0–51.6 cm) and 39.9 cm (27.4–51.3 cm)) and for circuit 1100 ($t = -3.54$; df $= 133$, $P < 0.001$; 41.2 (36.9–53.5 cm) and 38.6 cm (32.2–50.0 cm)).

DBH values for poles with more than one PW orifice were significantly higher than for those with a single PW orifice for circuit 1475 ($P = 0.013$; 46.1 and 41.0 cm; $n = 17$ and $n = 11$) but not for circuit 1100 ($P = 0.46$; 41.1 and 41.3 cm; $n = 9$ and $n = 15$). On circuit 1475, three of the five poles with the greatest DBH had PW orifices, including three of the four poles with the highest numbers of orifices. On circuit 1100, three of the five poles with the largest DBH had PW orifices.

The percentage of creosote estimated was significantly higher in poles with at least one PW orifice than those without orifices on circuit 1475 ($P = 0.025$; 8.2 and 6.4%; $n = 19$ and $n = 170$) and on circuit 1100 ($P = 0.041$; 6.3 and 1.6%; $n = 24$ and $n = 111$). It is important to note that means were low and null values very high.

The average number of major cracks did not differ between poles with at least one orifice and poles without orifices on circuit 1475 ($P = 0.903$; 0.25 and 0.23 crack/pole; $n = 28$ and $n = 191$). On circuit 1100, however, the average number of major cracks was higher for poles without orifices than for poles with at least one orifice ($P = 0.041$; 1.35 and 0.83 crack/pole; $n = 112$ and $n = 23$).

DISCUSSION

Results indicate that PW are responsible for the majority of damage caused by woodpeckers on poles of circuits 1475 and 1100 in the segments studied. PW nesting/roosting orifices are the holes most damaging for poles. According to Rumsey (1968), PW feeding activities are not a threat to poles. Several studies point to the fact that woodpeckers mainly attack poles to excavate nesting/roosting holes (Turcek, 1960; Dennis, 1964; Millar, 1992; Bevanger, 1997). Small PW holes observed on the lines studied probably were, as suggested by Rumsey (1968), exploratory holes made when searching for a site to excavate a nesting hole.

There is no study which quantified the number of exploratory holes on natural supports (trees). In Alberta, Bonar (2000) surveyed PW orifices with an entrance more than 12 cm deep, but did not go further down inside the tree trunk; they represented 13% of all nesting orifices that he found.

On poles in Texas, Dennis (1964) counted 15 nesting/roosting cavities out of a total of 302 PW holes on lines. The ratio of the number of these holes to the number of nesting/roosting orifices is twenty, which is much higher than that observed in the present study (2.4 and 1.9). In Manitoba, McIlraith and Berger (2000) do not mention exploratory holes; they consider two types of holes; those for feeding and those for nesting/roosting. The ratio of the first over the second is 3.3. It is likely that some of their feeding holes were really exploratory holes.

The greater heights of nesting/roosting cavities on circuit 1475 than on circuit 1100 could be attributable, in part, to the slightly greater diameter of poles on circuit 1475. It is probable that, in as much as the diameter permits it, PW prefer to nest higher, to reduce predation risks. Large trees offer a greater protection against predation because nests can be built higher (Nilsson in Harestad and Keisker, 1989).

Despite the large number of PW nesting/roosting orifices observed on the two lines studied, the number of orifices excavated in 2001 and 2002 and the mean annual number excavated since the construction of the lines suggest that only a few new orifices are excavated each year. In Manitoba, McIlraith and Berger (2000) observed about 20% of new orifices (nesting/roosting) in 2000 compared to 2.0 and 2.6% for the present study.

Results suggest that sealing orifices leads PW to excavate new ones to reach the cavities. Since old cavities are rarely used a second time for nesting (Bent, 1939; Bull et al., 1992; Bull and Jackson, 1995; Bonar, 2000), it is probable that many of the orifices that we observed are used sometimes for roosting. Several studies (McClelland and McClelland, 1999; Bonar, 2000; Kilham, 1979; Bull, 1987) state that resting/roosting cavities are former nesting cavities. In addition, they often present more than one orifice (Bull et al., 1992; McClelland and McClelland, 1999; Bonar, 2000). This characteristic and the sealing of orifices could explain the disparity between the estimated number of cavities for the two lines and the number of nesting orifices (88 vs 133). A similar phenomenon was described by Bull et al. (1992) in Oregon; PW use hollow trees for resting, however, it excavates orifices to reach these natural cavities. This indicates that it is probably useless to seal PW orifices, because it will trigger the excavation of new ones to reach cavities, thus possibly weakening even more a given pole.

Results indicate that a small portion of cavities dug by PW are occupied by secondary users. According to Bonar (2000), direct observations greatly underestimate the occupation by secondary users. In addition, occupation by secondary users fluctuates over the seasons. It is probable that, on the lines studied, other animal species occasionally use PW cavities in poles.

Despite the higher percentage values of creosote on poles with at least one PW orifice than for those without orifice, the low values associated with this variable along with the large number of zero values point to a coincidence without biological meaning. Results indicate that PW avoid establishing a nesting cavity in a pole with many cracks.

DBH comparisons indicate that PW select the biggest poles to excavate nesting/roosting cavities. Bull et al. (1986) determined that PW selected the biggest trees available for nesting. These results strongly suggest that PW establish nests in poles because they present a larger diameter than adjacent trees. Millar (1992) in a study in Manitoba, suggests the same hypothesis. According to Bevanger (1997) large poles could represent some form of super stimulus, and he suggested that this is the most probable hypothesis to explain woodpecker attraction to poles.

One advantage of nesting in larger poles and larger trees is that it provides a thicker wall around the nest, along with increased insulation and protection against predation. It also reduces the risk that the support will break at the site of the cavity (Harestad and Keisker, 1989). Millar (1992) observed in Manitoba that black bear climbed a few poles harbouring PW nesting cavities. During the present study, signs of black bear were noted at the base of a few poles. It is possible that on occasion, black bears open PW cavities and those of other woodpecker species containing eggs or young when the wood is partially decomposed.

CONCLUSION

PW was responsible for the great majority of damage caused by woodpeckers to poles of the two lines studied. Nesting/roosting cavities of that species represent by far the worst damage. Small holes dug by PW on poles are probably exploratory holes when searching for a favourable site for a nesting cavity.

The numbers of new nesting/roosting orifices and cavities excavated on poles each year by PW appear low. Results indicate that plugging and/or sealing a cavity incites PW to excavate a new orifice to reach the cavity, which in turn could weaken the pole. A small proportion of cavities dug by PW in poles are occupied by secondary users.

The height and especially the diameter of poles represent selection factors very important for PW when choosing a pole to excavate a nesting cavity. PW used the largest poles, suggesting that diameters of poles are greater than diameter of trees in the adjacent forest.

To better understand the problem, we need to address the following in a future phase of this study. We need to determine the number of new orifices excavated annually by PW on the two lines studied. Finally, we must determine the availability of suitable trees for nesting in the adjacent forest to validate the hypothesis relative to the importance of pole diameter. Only then do we feel that we will be able, from an ecological perspective, to address the solution with some confidence.

REFERENCES

Bent, A.C. 1939. Life histories of North American woodpeckers. U.S. National Museum Bulletin N° 174.

Bevanger, K. 1997. Woodpeckers, a nuisance to energy companies. Fauna norv. Ser. C. Cinclus, 20: 81–92.

Bonar, R.L. 2000. Availability of Pileated Woodpecker cavities and use by other species. Journal of Wildlife Management, 64(1): 52–59.

Bull, E.L. 1987. Ecology of the Pileated Woodpecker in northeastern Oregon. Journal of Wildlife Management, 51: 472–481.

Bull, E.L., S.R. Peterson, and J.W. Thomas. 1986. Resource partitioning among woodpeckers in northeastern Oregon. U.S. Forest Service Research Note PN-444.

Bull, E.L., R.S. Holthausen, and M.G. Henjum. 1992. Roost trees used by Pileated Woodpeckers in northeastern Oregon. Journal of Wildlife Management, 56: 786–793.

Bull, E.L. and J.A. Jackson. 1995. Pileated woodpecker (*Dryocopus pileatus*). In The Birds of North America, no. 148 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Dennis, J.V. 1964. Woodpecker damage to utility poles: with special reference to the role of territory and resonance. Bird-Banding, 35: 225–253.

Harestad, A.S. and D.G. Keisker. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. Canadian Journal of Zoology, 67: 1067–1073.

Kilham, L. 1979. Courtship and the pair-bond of pileated woodpeckers. Auk, 96: 587–594.

McClelland, B.R. and P.T. McClelland. 1999. Pileated woodpecker nest and roost trees in Montana: links with old-growth and forest "health." Wildlife Society Bulletin, 27: 846–857.

McIlraith, A. and R. Berger. 2000. Prevention of pileated Woodpecker (*Dryocopus pileatus*) damage on Manitoba Hydro utility poles. Year 2000. Myrica Systems inc., Manitoba Hydro. 67 pp.

Millar, B.R. 1992. An ecological assessment of the use of Hydro utility poles for nesting by Pileated Woodpeckers in southeastern Manitoba. Master of Natural Resources Management, University of Manitoba, Winnipeg, Manitoba. 91 p.

Rumsey, R.L. 1968. A pole's-eye view of woodpeckers. Forests and People. Second Quarter. pp. 38–40.

Turcek, F.J. 1960. On the damage by birds to power and communication lines. Bird Study, 7: 231–236.

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Ospreys and Transmission Lines in Lake Houston, TX: Problem and Solution

David C. McAden

In 1997, a transmission line traversing Lake Houston on wood H-Frame structures had to be replaced due to deterioration of the poles. Space was available in the 100-ft. wide right-of-way (ROW) to place a concrete pole line 20 feet inside the ROW. A complicating factor was that a pair of Ospreys (Pandion haliaetus) had built a nest on the top horizontal crossarm of one of the H-Frame structures. The nest was first observed by a local resident in 1993, and had been utilized by the Osprey pair every year since. U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department biologists recommended leaving the structure in place rather than moving the nest to a new structure away from the ROW. The Ospreys leave the lake in early July and return in late January to start nesting, so construction was completed between July and September. In 2002, a steel pole line had to be built across the lake, parallel to and north of the concrete pole line. The Osprey nest H-Frame would have been between the two lines, which was deemed unacceptable both operationally and for the welfare of the Ospreys. A permit was acquired from the U.S. Fish and Wildlife Service to allow the relocation of the nest outside of the existing ROW, and the nest was successfully moved to the new platform in late October 2003. The adult Ospreys returned to the nest in February 2004 and had hatched their eggs, but a severe storm in May caused the young birds to be blown out of the nest. The adults survived the storm, and it is hoped that they will be more successful in 2005.

Keywords: Osprey, Nest Relocation, Lake Houston, ROW

INTRODUCTION

Lake Houston (Lat. 30.0° N., Long. 95.1° W.) is a man-made reservoir impounding the San Jacinto River in northeast Harris County, approximately 20 miles from downtown Houston (see Fig. 1). The lake serves as one of the primary sources of surface potable water for the Houston and Galveston metropolitan areas. The first electric transmission line was constructed across Lake Houston in 1953–54 within a 100-ft. wide right-of-way (ROW) obtained from the City of Houston.

In early 1996 Houston Lighting and Power Company, the predecessor company of CenterPoint Energy (CNP), determined that the 138 kV transmission line traversing Lake Houston for 1.6 miles on wood H-Frame structures had to be replaced due to deterioration of the wood poles beneath the water surface. There was adequate room in the 100-ft. wide ROW to place a concrete pole line 20 feet inside the ROW, 30 feet south of the existing line, but a complicating factor was that a pair of Ospreys (*Pandion haliaetus*) had chosen to build a nest on the top horizontal crossarm of the H-Frame structure nearest to the west side of the lake. The nest was first observed by a local resident in 1993, and had been utilized by the Osprey pair every year since then. U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPWD) biologists recommended leaving the structure holding the nest in place rather than moving the nest to a new structure away from the ROW. TPWD stated at the time that this was one of only three nesting pairs of Ospreys in the State of Texas.

The Osprey nest almost became a moot issue in the Fall of 1996 when the female of the pair was struck by an automobile while attempting to land on the bridge crossing Lake Houston to the north of the nest site. A state-licensed bird rehabilitator, Mary Hall, was con-

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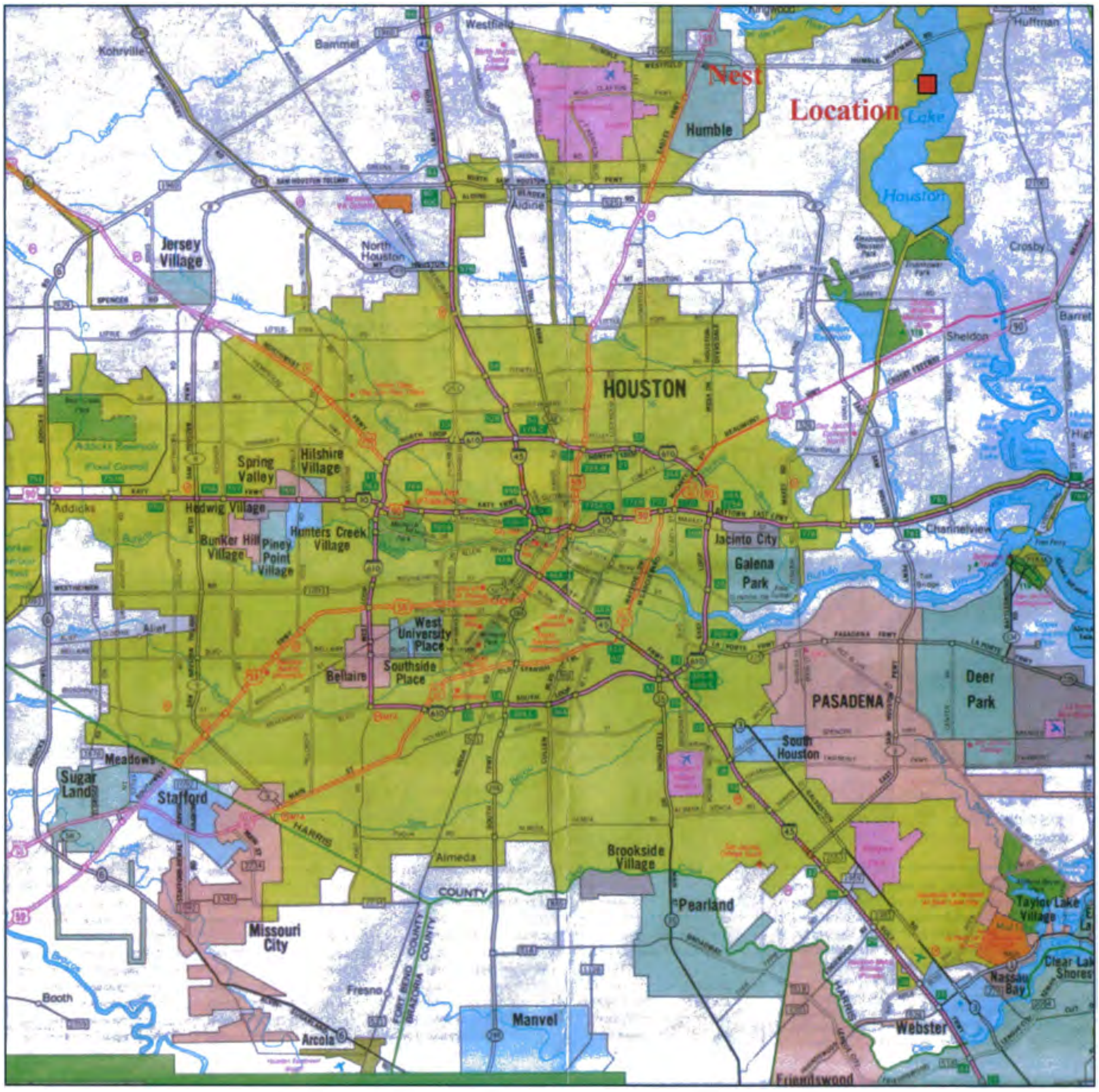

Fig. 1. Location of the osprey nest on Lake Houston.

tacted and she took the female to a local veterinarian, Dr. Michael Key, for examination (see Fig. 2). After treatment, Ms. Hall took the female Osprey to her rehabilitation facility and nursed her back to health before releasing her. The rehabilitation was obviously successful, since the pair returned to the nest in February 1997 and two young Ospreys were spotted in the nest in April 1997.

THE PROBLEM

CNP made plans to rebuild the line adjacent to the old H-Frame line and remove all of the H-Frame structures except for the one holding the Osprey nest. Figure 3 is a photograph of the H-Frame line prior to the start of the rebuild project. Regulatory filings were made in May 1997, with the Public Utility Commission of Texas to authorize the rebuilding of the line, and construction start was timed to coincide with the fledging of the two young birds in late June-early July. Figure 4 shows a close-up of the Osprey nest, the two adult Ospreys, and one of the two young birds on June 4, 1997.

Somewhat of a public relations problem occurred prior to the start of construction when word started rapidly traveling throughout the local birding community, by means of the internet, that CNP planned to tear down the Osprey nest. Numerous phone calls were received from concerned citizens, and they were informed that CNP had no such intentions and was, in fact, delaying construction until the young Ospreys had left the nest to ensure that no harm was done to them. Flyers were placed on the doors of all the homes fronting on the shoreline of Lake Houston to inform the residents of the pending construction schedule and the CNP's efforts to protect the Ospreys.

METHODS

The line rebuild project was started in early July on the east side of the lake to allow the young Ospreys time to develop their flying skills before the construction activities would be close to their nest structure. A barge and crane with a steam-powered pile driver was used to drive sections of 3.5-ft. diameter steel pipe (casing) vertically into the lake bottom. These casings served as the foundation to support the concrete transmission line poles. The top elevation of the casings was set at one foot above the spillway elevation of the Lake Houston dam to make sure they would not be below the surface of the lake at any time. Figure 5 is an aerial photograph showing the barge and crane installing one of the foundation casings as well as one of the casings that had already been installed. Following foundation installation, a layer of limestone rock was placed in the casings, and the concrete poles were set in place and plumbed. More limestone rock was added to within a foot of the top of the casings and a final cap of concrete was poured into the casings to seal them. Next, insulators were attached to the poles, and the new conductor and static wires were strung. In late September 1997, the insulators, conductor and static wires were removed from the H-Frames, and all of them, except the one with the Osprey nest, were removed by breaking them off just above the lake bottom.

Fig. 2. Dr. Michael Key, veterinarian, with injured female osprey, November 1996.

In mid-October 1997, winds clocked at 60 mph at the nearby George Bush Intercontinental Airport moved through the area, and the Osprey nest was blown off of the H-Frame (see Fig. 6). Local residents started calling, insisting that the nest be placed back on the

Fig. 3. The original H-frame line crossing Lake Houston. One of the adult ospreys can be seen on the nest. Photo taken in early June, 1997.

Fig. 4. Close-up of the original osprey nest location on the H-frame prior to the start of construction in May, 1997. Note the young osprey beneath the adult bird perched on the nest.

Fig. 5. Foundation installation during the summer of 1997.

H-Frame. Volunteers from CNP constructed a crude support structure of 2″×4″ lumber and hardware cloth and attached it to the H-Frame structure (see Fig. 7). Although the nest itself was shattered and dispersed, several sticks were placed on the nest cradle. Then, the waiting game began to see if the nest would be used again the following breeding season. The Ospreys returned the next January, rebuilt the nest, and suc-

Fig. 6. The H-frame structure in October 1997, after the nest had been blown down by high winds.

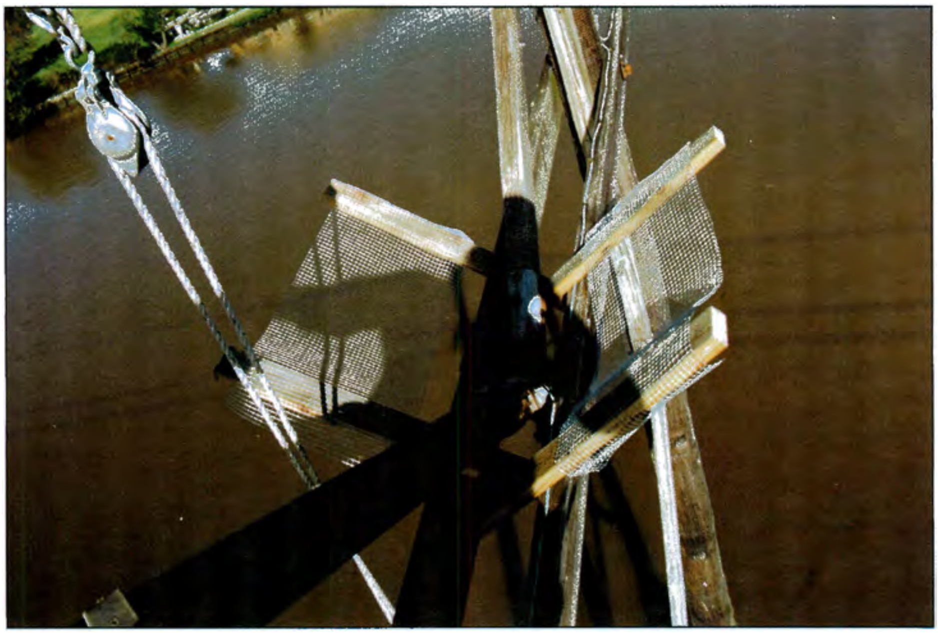

Fig. 7. Nest cradle installed on H-frame to provide additional stability for the nest during storm conditions. Photo taken in October 1997.

cessfully fledged two young birds in 1998, 1999, 2000, 2001, 2002 and 2003. Figure 8 is a photo taken in June 2002 and shows the results of the 2002 breeding season.

Meanwhile, the Texas Legislature passed Senate Bill 7 in 1999 to deregulate the electric industry in Texas. When the law went into effect in 2001, there was an influx of generating facilities planned for construction in the Houston area. As a result, in 2002 the need for a higher-capacity line across Lake Houston was identified, and it was determined that the existing concrete poles did not have sufficient capacity to support the new bundled conductor needed for the upgrade of the line. Additionally, the need for a new distribution line across Lake Houston was identified. Engineers decided that the existing transmission line would be rebuilt and the concrete pole line would be converted for use as a distribution line. A new double-circuit steel pole line would have to be constructed across the lake, parallel to and north of the concrete pole line. Construction of the steel pole line was scheduled to start in late summer of 2003 so it would have no impact on the Ospreys' nesting activities. The same type of steel casing foundation was used, but the diameter of the

Fig. 8. Osprey nest on H-frame in June 2002. Note the four ospreys, one on the upper crossarm and three on the lower horizontal beam.

Fig. 9. Installation of the foundation casings for the construction of the steel pole line across Lake Houston. Note the diameter of the casing suspended from the crane compared to the concrete pole foundations installed in 1997. Photo taken October 13, 2003.

casing was considerably greater (6.7 ft. vs. 3.5 ft.). The installation of the steel pole foundations is illustrated in Fig. 9.

Leaving the Osprey nest on the H-Frame structure was deemed unacceptable from an operational standpoint because maintenance work would have to be scheduled around the presence of the Ospreys, especially when there were eggs or young in the nest. There was also concern for the welfare of the Ospreys due to increased risk of wire strikes. A permit was acquired from the USFWS to allow CNP to relocate the nest outside of the existing ROW to a new platform mounted

Fig. 10. Osprey nest after being removed from H-frame structure and prior to being installed on the top of the new concrete pole structure. Photo taken November 4, 2003.

Fig. 11. Osprey nest being raised in preparation to attaching it to the top of the new pole.

on a concrete pole about 250 feet south of the original location. The City of Houston granted a new 10-ft. × 10-ft. easement for the new pole and nest platform, and the nest was moved intact to the new platform in late October 2003 (see Figs. 10–13). Finally, the H-Frame structure was removed, resulting in the lake crossing and Osprey nest pole appearing as shown in Fig. 14.

In February 2004, the adult Ospreys returned to the nest, and readily accepted the new nest location. They immediately started adding plant materials to the existing nest and the female began setting on eggs in

Fig. 12. Osprey nest being attached to the new concrete pole structure.

Fig. 13. Close-up of osprey nest on top of the new concrete pole structure.

March 2004. A visit to the nest site on March 23, 2004 showed one of the parents on the nest (Fig. 15), and another visit on April 15, 2004 resulted in photographs that showed one of the adults apparently tending to young birds in the nest, although they were never clearly seen (Fig. 16).

Fig. 14. Location of the osprey nest pole in relation to the transmission and distribution lines crossing Lake Houston. The original nest location was approximately midway between the two pole lines.

Fig. 15. One of the adult ospreys tending to the relocated nest during the early part of the 2004 breeding season. Note the green nest material recently added to the nest. Photo taken March 23, 2004.

Fig. 16. Adult osprey feeding one of the young birds on April 15, 2004.

Fig. 17. Osprey nest on May 21, 2004, following the severe thunderstorm that eradicated the 2004 young-of-the-year ospreys.

CONCLUSIONS

A site visit on May 21, 2004 revealed that another misfortune had occurred to the Ospreys. A severe thunderstorm had passed through the area the previous week, and although a tornado funnel was not actually spotted, the tops of several tall pine trees in the neighborhood had been sheared off by high winds. The adult pair had been spotted immediately after the storm carrying nest material up to the nest, but they stopped coming around the nest after a day or so, indicating that there were no young birds left in the nest. Apparently, it was too late in the year for them to start incubating a new set of eggs, so the production from the 2004 breeding season will be zero. The good news is that the adults did not appear to be injured by the storm, and the nest was not damaged to any great extent (see Fig. 17). CNP must now wait for the late winter-early spring of 2005 to arrive and hope that the Ospreys in Lake Houston have a more successful breeding season than in 2004.

CNP believes that the nest relocation was a success, in spite of the failure to produce young Ospreys in 2004. The Ospreys and their nest will continue to be monitored in the years ahead.

BIOGRAPHICAL SKETCH

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David McAden has worked for CenterPoint Energy and its predecessor companies since September 1970 in the Environmental, Right-of-Way Planning, and Transmission Operations Departments. From 1970 through 1987, in the Environmental Dept., he was responsible for conducting aquatic surveys of estuarine zooplankton, fishes and crustaceans in conjunction with the construction and operation of several generating plants on Galveston Bay, and he worked on a team conducting both aquatic and terrestrial surveys during the pre-operational phase of the South Texas Plant (nuclear) in Matagorda County, Texas. From 1988 through the present, in both Right-of-Way Planning and Transmission Operations, he has coordinated with routing consultants in the preparation of routing studies and environmental assessments for numerous applications filed with the Public Utility Commission of Texas for electric transmission line projects. He also works with state and federal agencies to acquire necessary permits when transmission facilities potentially impact threatened and endangered species, migratory birds, and wetlands. He received both a Bachelor of Science (1970) and a Master of Science (1977) degree in Wildlife and Fisheries Sciences from Texas A&M University.

Bald Eagle (*Haliaeetus leucocephalus*) Electrocutions and Artificial Food Sources in Alaska

Richard E. Harness

Although there is no nationalized database of raptor mortality, the United States Fish and Wildlife Service (USFWS) maintains a centralized reporting system in Alaska. According to these database records, Alaska has documented 231 confirmed bald eagle electrocutions from 1978 to 2002. March through September 2002, EDM biologists visited electric utilities in Alaska to inspect distribution three-phase power poles. The areas surveyed have a history of bald eagle electrocutions and the purpose of the surveys was to identify high-risk overhead electric distribution structures for electrocutions in order to develop proactive retrofitting standards. Alaska power line electrocutions centered at artificial food concentration areas such as canneries, fish cleaning stations and municipal waste facilities. These food sources attract large numbers of eagles in the winter, sometimes resulting in feeding frenzies. When eagles concentrate in large numbers they land on a variety of problematic structure types and occasionally fly into energized wires. Alaska retrofitting includes the insulation of exposed jumpers, equipment, perch deterrents, and in some situations, the complete covering of conductors to prevent fly-ins. Although retrofitting will reduce the risk of power line contacts, reducing artificial food sources is a critical component of reducing risks to eagles in Alaska.

Keywords: Bald eagle, electrocution, collision, distribution power line, Alaska, cannery, waste facility, fish cleaning station, power line retrofitting, right-of-way

BACKGROUND

During the 1970s and early 1980s, electric industry efforts to reduce raptor electrocutions in the United States were widespread and coordinated, but predictions about mitigating the problem were overly confident and today, raptors continue to be electrocuted, possibly in great numbers (Lehman, 2001). Although there is no nationalized database of raptor mortality, the United States Fish and Wildlife Service (USFWS) maintains a centralized reporting system in Alaska. According to these database records, Alaska has documented 231 confirmed bald eagle (*Haliaeetus leucocephalus*) electrocutions from 1978 to 2002 (USFWS, 2003). These records lack another fifty electrocution records between 2002 and 2003 (J. Birchell, USFWS, unpublished data). In bordering British Columbia, between 1986 and 1998 Wayland et al., (2003) documented electrocution as the number one cause of known mortality for bald eagles ($n = 50$) with only the undetermined cause of death ($n = 123$) exceeded documented electrocutions.

From 2001 to 2002, EDM International, Inc. (EDM) biologists worked with utility companies in Alaska to mitigate bald eagle electrocutions. A pattern analysis focusing on power line unit configuration, geographic location, and habitat was used because not all utility poles are at equal risk. Raptors will select certain poles over others and these "preferred perches," if unprotected, are more likely involved in electrocutions (APLIC, 1996). Because the power companies have thousands of miles of power lines, the surveys first focused on poles with historic mortality. Lines near artificial food sources (e.g. landfills, fish canneries, sport

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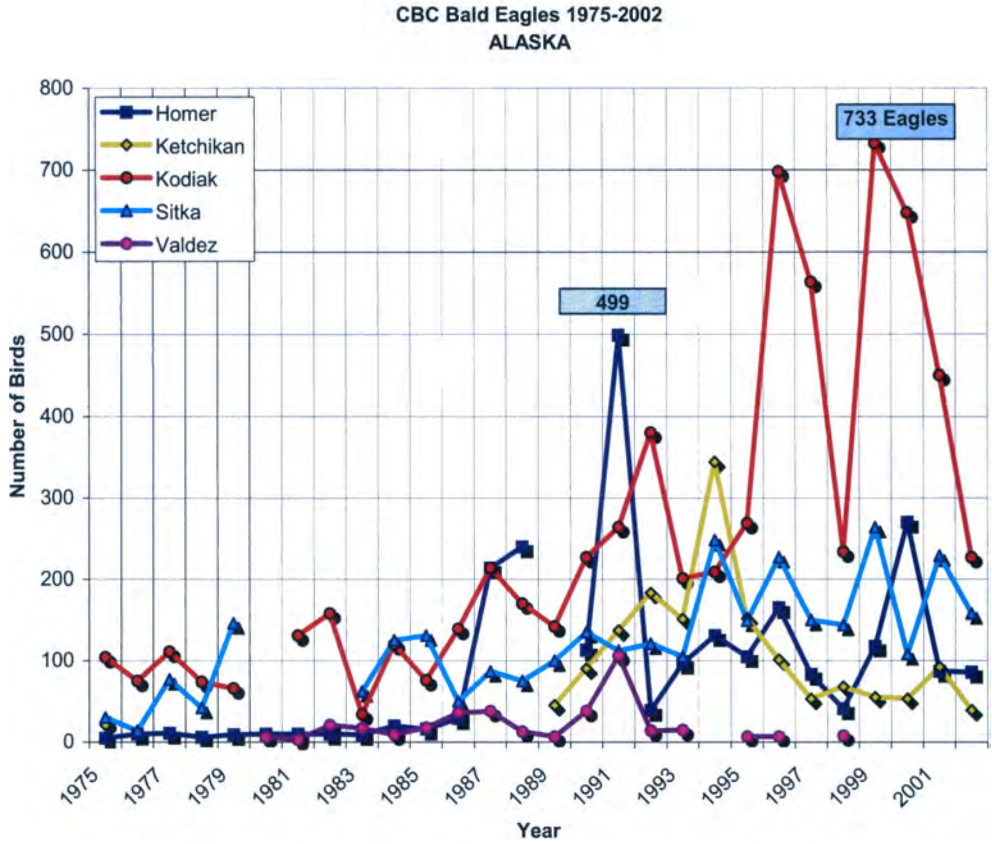

Fig. 1. National Audubon Society 1975–2002 Christmas bird count data.

fish cleaning stations) and natural food sources (e.g. salmon streams, tidal flats) were also surveyed. Finally, power lines near nest locations were also inspected. Other sections were spot-checked. This strategy to focus on specific areas was used because geographic location and habitat setting are as important as the technical utility pole design in determining the actual risk of electrocution (Mañosa, 2001). This information was combined with the pole configuration risk to prioritize retrofitting.

ALASKA SURVEY AREA

According to Jacobson and Hodges (1999), the southeastern Alaska adult bald eagle population in 1997 was 13,327. This is an increase of 92% from the 1967 population and is largely due to the repeal of the 1917–1953 Alaska eagle bounty (Hodges et al., 1979). Bald eagles are adaptable to a wide variety of natural and artificial settings, including highly urbanized environments. Eagles congregate at both natural food sources such as salmon streams, and artificial locations such as canneries and landfills. The increasing number of birds in urbanized areas has created problems for the electric utilities. Although the mortality is not thought to be biologically significant, electrocutions are violations of the Eagle Protection Act and the Migratory

Table 1. Confirmed Alaska bald eagle electrocutions from 1990–2002

Confirmed Alaska electrocutions 1990–2002	
Homer	26
Ketchikan	6
Kodiak	16
Sandpoint	21
Sitka	45
Valdez	1

Bird Treaty Act and utilities have been fined for bird electrocutions.

During 2001 and 2002, power lines were inspected in and around Homer, Ketchikan, Kodiak, Sandpoint, Sitka, and Valdez, Alaska. During the 1990's, these areas experienced significant increases in winter eagle numbers according to Christmas Bird Count (CBC) data (Sauer et al., 1996). According to these data, peak eagle numbers for Homer, Ketchikan, Kodiak, Sitka, and Valdez were 499, 344, 733, 229, and 106 birds (Fig. 1).

ARTIFICIAL FOOD SOURCES AND EAGLE MORTALITY

USFWS historic electrocution mortality for Homer, Ketchikan, Kodiak, Sandpoint, Sitka, and Valdez, Alaska are provided in Table 1 (USFWS, 2003). USFWS records for the Alaskan Kenai Peninsula from 1990–2002 also include three additional eagle power line collisions (USFWS, 2003). During EDM field inspections it became clear that detected electrocutions occurred more frequently at artificial food sources. For example, eight of 26 recorded eagle interactions along the Kenai Peninsula occurred at the Homer Landfill and three more at the Soldotna Landfill. A single pole located near a home where the landowner fed eagles killed another two birds and another two eagles were electrocuted at fish processing plants. This utility has approximately 1,105 miles of overhead distribution lines yet 15 detected electrocutions (57% all detected Kenai Peninsula eagle interactions) were associated with only 10 electric poles near artificial feeding sites.

Fish canneries also attract large numbers of eagles. During one week in 2000, five eagles were electrocuted in Sitka as herring boats returned to the port with their catch. The eagles were drawn to the processing plants to wait for scraps, perching on nearby poles for feeding opportunities (Federal Wildlife Officers Association, 2000). Similarly, three eagles were killed near the Kodiak cannery and twelve eagles were electrocuted in Adak near the local fish processing plant. One eagle was killed after flying into a building after a fish tote spilled and a feeding frenzy ensued at a Kodiak cannery (Lanny Van Meter, Kodiak Electric Cooperative, personal communication). In 1999 a total of thirty eagles were electrocuted in Adak and an additional five eagles were electrocuted near a Sand Point fish processing plant located on Unga Island (Federal Wildlife Officers Association, 1998 and 2000). During EDM's field surveys 23% of all eagle mortality detected on the Homer, Ketchikan, Kodiak, Sandpoint, and Valdez electric systems occurred at a few dozen poles at locations near either fish processing plants or landfills. Raven electrocutions were also noted at single-phase transformers located near open dumpsters, which can attract an unusually high number of birds.

Feeding by individuals can also lead to electrocution problems. In Eagle River, an adult bald eagle was electrocuted after feeding on a pile of meat placed on the road by a woman. This was the second eagle killed by electrocution at this location within two months. A similar eagle electrocution occurred in Homer near a three-phase distribution power line at the waters edge. In both cases, the utility company was informed of the need to insulate power lines in the area and the landowners were asked to stop feeding the eagles.

ALASKA RETROFITTING

Existing Alaska retrofitting primarily included perch management and the insulation of exposed jumpers

Fig. 2. Pole raptor protected with a conductor guard.

and installing bushing covers on equipment. Unfortunately, the use of perch deterrents such as triangles reduces mortality, but will not eliminate it, especially when large numbers of birds congregate around a few poles (Harness and Garrett, 1999). Conductor guards (Fig. 2) were specified by EDM in areas where birds concentrate, as these devices allow birds to safely perch on crossarms. It is important to note that there is much unknown about how well various retrofitting products will stand up to Alaska's harsh winter environment. In many cases, the decision to select a particular product was based upon how well it was thought the product would perform from an electrical and mechanical standpoint. Testing of these products is a current research need. As with all retrofitting, lineman safety was the preeminent consideration.

In some places the extreme density of eagles made retrofitting power lines a more difficult task with electrocutions persisting even after perch management, and covering jumpers and equipment. In these cases, some line segments were ultimately placed underground despite the cost and difficulty of burying lines in rocky soil.

In addition to electrocutions, eagle fly-ins were recorded. A fly-in is a bird collision that also results in an electrocution. In Sitka, a bald eagle fly-in occurred on a line with 60-inches of separation. Despite the "raptor friendly" clearance, the colliding bird had enough force to push two midspan wires together resulting in a collision and electrocution. Post retrofitting fly-ins also were reported on Kodiak Island near artificial food sources (pers. comm. Lanny VanMeter). It is important to note that fly-ins can be very difficult to mitigate and an isolated collision event by a bird does not generally warrant mitigation. Raptors have excellent eyesight and are not generally associated with collision problems (Olendorff and Lehman, 1985). Collisions often occur under conditions of low lighting or when weather restricts visibility. Collisions can also occur when birds are distracted. One fly-in witnessed by a utility customer in Sitka occurred when an immature bald eagle flew into a distribution power line while being pursued by two other birds.

ALASKA PERCHING AND NESTING TREES

Another important component of eagle electrocution protection is protecting natural perch sites. Eagles in Alaska frequently perch on whatever is available along the ocean, mud flats, or near a food source, thus requiring changes to poles in some areas. The U.S. Forest Service (USFS) owns 80% of the land in southeast Alaska and requires a protection zone of 100 m of an eagle nest site (Jacobson and Hodges, 1999). This provides a buffer of tall trees and makes shorter power poles less attractive perch sites for fledgling birds. Power poles with open exposure near nest sites are at greater risk and should be retrofitted. In Sitka, there is concern that the removal of trees near a cannery may result in birds using urbanized utility poles as substitute perches. The protection of trees is an important component of reducing raptor electrocution mortality and other Alaska communities should encourage the protection of prime perching areas.

CONCLUSION

Alaska utilities have begun to retrofit power lines in order to mitigate bird electrocutions due to recent law enforcement actions. Because there are thousands of miles of line, Alaska utilities are seeking ways to identify high-risk areas for immediate retrofitting. A review of lines with historic mortality suggests that bald eagle power line electrocutions concentrate at artificial food areas such as canneries, fish cleaning stations, and municipal waste facilities. On the Kenai Peninsula 57% of all detected eagle interactions ($n = 26$) were associated with only 10 electric poles, all located near artificial feeding sites. EDM also inspected power lines for the Homer, Ketchikan, Kodiak, Sandpoint, and Valdez electric systems where 23% of all detected eagle mortality ($n = 89$) occurred at a few dozen poles at locations near either fish processing plants or landfills. Retrofitting should prioritize at these locations and new lines should simply be constructed with adequate clearances for eagles, using 60 inches of separation (APLIC, 1996).

Artificial food sources attract large numbers of eagles in the winter, sometimes resulting in feeding frenzies. When eagles concentrate in large numbers, they land on a wide variety of utility structure types and occasionally fly into energized wires. Alaska retrofitting includes the insulation of exposed jumpers, equipment, perch deterrents, and in some situations, the covering of primary conductors to prevent fly-ins. Although retrofitting will reduce the risk of power line contacts, reducing artificial food sources is a critical component of reducing risks to eagles in Alaska. When hundreds of eagles concentrate in a small area with power lines, there will likely be negative interactions, despite the best retrofitting efforts. In these cases, complete rebuilding or undergrounding is the only effective option, although very expensive. Rerouting the lines is not an option as power is required as these facilities.

REFERENCES

Avian Power Line Interaction Committee (APLIC). 1996. Suggested practices for raptor protection on power lines: the state of the art in 1996. Edison Electric Institute/Raptor Research Foundation. Washington, D.C. 125 pp.

Federal Wildlife Officers Association. 2000. The Federal Wildlife Officer News Letter – Spring. Vol. 13, No. 2.

Federal Wildlife Officers Association. 1998. The Federal Wildlife Officer News Letter – Fall. Vol. 11, No. 3.

Harness, R.E. and M. Garrett. 1999. Effectiveness of perch guards to prevent raptor electrocutions. Journal of the Colorado Field Ornithologists Vol. 33, No. 4: 215–220.

Hodges, J.J., J.G. King, and F.C. Robards. 1979. Resurvey of Bald Eagle breeding population in southeastern Alaska. Journal of Wildlife Management 43: 219–221.

Jacobson, M.J and J.I. Hodges. 1999. Population trend of adult bald eagles in southeast Alaska, 1967–97. Journal of Raptor Research 33: 295–298.

Lehman, Robert N. 2001. Raptor electrocution on power lines: current issues and outlook. Wildlife Society Bulletin 29: 804–813.

Mañosa, S. 2001. Strategies to identify dangerous electricity pylons for birds. Abstracts from the 4th Eurasian Congress on Raptors. Seville, Spain. 25–29 September 2001. Raptor Research Foundation.

Olendorff, R.R. and R.N. Lehman. 1985. Abstract: Raptor collisions with utility lines: an analysis using subjective field observations. Abstract of paper. In: 1985 Raptor Research Foundation Symposium on the Management of Birds of Prey: International Meeting, Abstracts of papers. Symposium held in Sacramento, California, November 1–10, 1985. Page 14–15. (Session 10: Second Raptor Research Foundation on Raptor Conservation Techniques, November 9–10).

Sauer, J.R., S. Schwartz, and B. Hoover. 1996. The Christmas Bird Count. Patuxent Wildlife Research Center, Laurel, MD. Version 95.1. (http://www.mbr-pwrc.usgs.gov/bbs/cbc.html (May 8, 2003)).

United States Fish and Wildlife Service (USFWS). 2003. USFWS Alaska Raptor Electrocution Database (Updated May 7 2003). USFWS – LE. Anchorage, Alaska.

Wayland, M., L.K. Wilson, J.E. Elliot, M.J.R. Miller, T. Bollinger, M. McAdie, K. Langelier, J. Keating, and J.M.W. Froese. 2003. Mortality, morbidity, and lead poisoning of eagles in western Canada, 1986–98. Journal of Raptor Research 37: 8–18.

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Mr. Harness is a certified wildlife biologist working for the engineering firm, EDM International, Inc. located in Fort Collins, Colorado. He has a B.S. in Fishery and Wildlife from the University of Missouri and a M.S. in Fishery and Wildlife Biology from Colorado State University where his thesis work was conducted on raptor electrocutions. Mr. Harness has 22 years experience managing and supervising environmental studies and research for the electric utility industry. His specific areas of strength are in wildlife-utility interactions including power line electrocutions and bird collisions. He is presently working with 26 utilities from Alaska to Florida developing Avian Protection Plans and directing research on woodpecker damage to utility poles and research on squirrel caused outages.

Cooperative Efforts by the Bonneville Power Administration to Promote Ferruginous Hawk Nesting on the Department of Energy's Hanford Reservation in Washington State

William T. Erickson, James W. Watson, and Bill Hubbard

The ferruginous hawk (*Buteo regalis*) was once common to the grassland areas of Washington State. It is the largest soaring hawk in the US. The Washington State Department of Fish and Wildlife has identified nine territorial pairs that are using Bonneville Power Administration towers on the Hanford Reservation site in Central Washington. These pairs represent 18% of the active nesting population in 2002 of this threatened species as designated by the State. Ferruginous Hawks did not range widely on the Reservation until specific transmission towers were introduced on the reservation in the 1970s. The nests are 2–3 feet in diameter and are made of interwoven sagebrush stems in the lower part of the transmission tower body. To provide a better nesting site for the hawks, wood nesting platforms were installed in the winter of 2003. These platforms are one-meter in diameter and are designed to prevent the nest from blowing out of the tower during high winds. A review of the nest platforms during the summer of 2003 indicated that at least one breeding pair that produced fledgling young occupied one nest. In 2004, with the assistance of ThermoSight, Inc, a remote camera was installed over the nest to observe and record the hawks during the nesting season.

Keywords: Ferruginous hawk platforms, transmission towers, remote video cameras

INTRODUCTION

The Bonneville Power Administration (BPA) as a matter of practice has involved itself in many cooperative efforts to help promote wildlife issues and practices on our rights-of-way. In the spring of 2002, the Washington State Department of Fish and Wildlife (WDFW) contacted BPA requesting assistance to modify some of the tower structures on the Hanford Reservation which is managed by the Department of Energy (DOE) to help improve the nesting survival of the ferruginous hawks (Buteo regalis) that nest in specific tower structures in the area (Watson, 2003). The WDFW, has been carrying out a cooperative study of the ferruginous hawk in the central Washington region since 1999 (Watson and Pierce, 2001).

BPA responded to the request by having two nesting platforms built by local high school students from Prescott, Washington, and then installed in the winter of 2003 by BPA. In 2003, both nest platforms were successfully occupied and the hawks raised young. In 2004, two more platforms were built and installed in BPA structures. In the late winter of 2004, with a grant from the Woodland Park Zoo, BPA linemen at one of the nesting sites installed a remote control camera (ThermoSight, Inc.) The camera will provide detailed behavior information of nesting hawks for ongoing WDFW research.

HANFORD RESERVATION AREA

The Hanford Site is located in central Washington and was created in 1943 by the War Department as the location for the Manhattan Project's Program to produce and purify plutonium for the War effort of World War II (Fig. 1). The site was selected because of

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Fig. 1. Location of the Hanford Reservation (DOE, 1999).

Fig. 2. Hawk's nest in lower part of tower atop the lower cross-members.

the remote location, favorable climate, the abundance of electricity from the Bonneville and Grand Coulee Dams, and clean water from the Columbia River (DOE, 1999).

The Hanford site is unique since the boundary encloses 1,517 square kilometers (586 sq mi) of large areas of nearly pristine shrub-steppe (big sagebrush) vegetation with minimal disturbance or activity on potential wildlife habitat, because the majority of the reservation is not accessible to the public. The site is also bisected by the last free flowing stretch of the Columbia River that represents 36 sq km of water surface area within the reservation boundaries. Up until 1943, approximately 80 percent of the area was utilized for grazing and cropland uses (DOE, 1999).

Part of the legacy of the Hanford site is that for 40 years the primary mission of the site was the production of nuclear materials for national defense. During the last ten years, there has been a change over from this nuclear mission to a restoration and cleanup program with emphasis on the natural resources of the site including wildlife and cultural resource management (DOE, 1999).

Since 1998, parts of the Hanford site have been designated as the Hanford Reach National Monument managed by the U.S. Fish and Wildlife Service. As this transition of management occurs from DOE to the U.S. Fish and Wildlife Service, coordination with the Monument staff in the future will be important since 4–5 ferruginous hawks nesting sites are in the designated National Monument area.

HAWK BIOLOGY

The ferruginous hawk (Buteo regalis) is the largest soaring hawk in the United States with a maximum wingspan up to 1.32 meters (5 ft). The species is common to the grasslands and steppe areas of the western United States. It ranges throughout 17 western States and 3 Canadian provinces during the breeding season and winters in the southwestern and south central U.S. and Mexico (Richardson et al., 1999).

Washington State is on the outer edge of the range of the ferruginous hawk. Traditionally hawks nested on the ground, rock crests or cliffs, or on occasion, trees. Due to the loss of shrub-steppe habitat by the conversion of this habitat to cropland, the species has declined due to the loss of nesting sites and prey associated with this conversion throughout the range of the hawk in the western United States (WDFW, 2000; Prairie Farm Rehabilitation Administration, 2003; Watson, 2003). The ferruginous hawk's status is a state threatened species listed by the State of Washington.

Adult breeding pairs of ferruginous hawks are monogamous and move over a wide range of their territory over the year. Washington ferruginous hawk individuals have been tracked to winter locations in central Baja Mexico and late summer locations in Montana and Canada (Watson, 2003). The breeding season in Washington starts in late February with courtship and territory establishment and lasts to mid August when the young reach full independence (Watson, 2003).

BPA'S INVOLVEMENT

Ferruginous hawks did not range widely on the Hanford Reservation prior to the 1970s until a specific BPA transmission tower type was built on the reservation (Fitzner and Newell, 1989). The tower, SC TYPE 2AL 18.48 meter (70 ft.) body appears to be the only tower type that is chosen by this species to nest. The hawks only build nests in the lower part of the tower atop the lower cross-members of the structure (Fig. 2).

Over the years, WDFW has identified nine (9) territorial pairs of ferruginous hawks that are using towers on the Hanford site. Four pairs are on the White Bluffs-451B line, four pairs are located on the Midway Benton #2 line, and one pair is on the Ashe-MHEW line near the old Hanford Town site. The approximate distance between nests is about 2.78 km. (2 miles) (Watson,

Table 1. Known nest sites of ferruginous hawks on the Hanford Site in 2004

Line name	Structure
Midway Benton #2	21/3 or 22/1
Midway Benton #2	23/1
Midway Benton #2	23/4
Midway Benton #2	26/1
Ashe MHEW #2	9/5
White Bluffs – 451B	5/3
White Bluffs – 451B	6/1 or 6/2
White Bluffs – 451B	7/4
Ashe-White Bluffs #1	9/3

2002a). These nine pairs represented 18% of the active nesting population in Washington state in 2002 (WDFW Wildlife Resource Data system).

The main threat to tower nesting birds is the wind which can blow these nests off the cross-members during the spring and summer, which is the critical period for the breeding and development of this species (Watson, 2002b). The nests are 0.52 to 0.8 (2–3 feet) in diameter and are made of interwoven sagebrush stems. Besides the obvious occupation of a nest in the tower, nesting sites can also be identified by the heavy amounts of sagebrush stems on the ground at the base of the nesting structure.

POTENTIAL BPA ACTIVITY IMPACT NEST SITES

This species is sensitive to human activities during the breeding season that occurs from early March to August of each year. During the nesting and incubation stages (March 1 to May 31), hawks could abandon nests even with the slightest disturbance by BPA activities (Richardson et al., 1999). These activities could include a climbing inspection, work on an adjacent structure, or a brief flyover by a patrol helicopter.

With assistance from the WDFW, BPA developed the following guidelines to minimize the effects of maintenance on these nesting sites:

- Activity buffers and periods of activities.
- Most critical period-incubation.
- Brief human access and intermittent ground-based activities should be avoided within a distance of 250 meters (820 ft.) of nests during this sensitive period (1 March to 31 May).
- Breeding season activities by BPA maintenance.
- Prolonged activities (0.5 hr to several days) should be avoided and noisy prolonged activities should not occur within 1 km (0.6 mi) of the nests during the breeding season (1 March to 15 August). Construction, major work, or other developments near occupied nests should be delayed until after the young have dispersed, which generally occurs about a month after fledging.

Helicopter patrols

BPA helicopter patrols should note the specific critical periods that may impact these nest sites. Avoid rotor wash on towers with visible nests present.

NESTING PLATFORMS

One of the initial goals of the project was to place a remote camera on one of the nests to observe the development of the hawks from nesting to the young adult stage. The main limitation of the hawks nesting in the BPA towers is that many of the nests are weakened by activity of the young and are blown out of the towers by high winds during the development period of March to August. Nestlings are often killed when nests fall. To solve this issue, BPA asked a local high school shop class to build platforms to install into BPA towers to make the nests more secure.

Prescott High School students from Prescott, Washington, Arturo Iglesias and Adrian Espinoza built two platforms that were installed on the two separate towers on the Hanford Reservation by BPA linemen from the Transmission Line Maintenance crew from Pasco, Washington on January 29, 2003 (Fig. 3) (Counts, 2003).

Table 2. Ferruginous hawks critical periods and approved BPA activities at the Hanford Site

Nesting event	Timing	Critical nature	Activities
Hawks on wintering area (outside the state of Washington)	Aug 15–Feb 20	None	Best time for tower maintenance/helicopter patrol-avoid helicopter wash over nests
Courtship/Territory establishment	Feb 21–Mar 20	Ensures nest activity	Emergency work, brief helicopter flights, brief visits to tower, nonessential climbing
Incubation	Mar 21–June 4	Essential to productivity	Emergency only, high probability of nest failure if tower is climbed. Only emergency helicopter patrols
Nestling	June 5–June 19	Young raised	Emergency only, brief flights, brief visits to tower, no climbing
Fledging	June19–Aug 14	Young independence	Emergency, avoid any prolonged tower activity – greater than 30 minutes

(Watson, 2002a)

Fig. 3. Arturo Iglesias and Adrian Espinoza with Fred Hassel, Stefan Schildt, and Gary Farran, BPA linemen from the Pasco Transmission Line Maintenance crew installing ferruginous hawks nest platform.

Fig. 4. Linemen "seed" ferruginous hawk nest platforms with sagebrush branches.

Platforms were one-meter in diameter and had 1.65 cm (¾inch) dowels around the edge to help prevent the nesting material from blowing away during a windstorm. This one-meter size was specified by the guidelines set by the WDFW (Richardson et al., 1999). After installing the platforms, the linemen "seeded" them with sagebrush branches to make the platform more inviting for the hawks to nest (Fig. 4). Both nest platforms were occupied within a few weeks after installation. At least one pair of hawks fledged young by July 2003.

VIDEO MONITORING

In winter, 2003, the WDFW initiated installation of a video camera on one tower with a nest platform to record ferruginous hawk nesting behavior. The remote location of the nest required use of a solar-powered camera and wireless transmission of the video signals for offsite recording and public internet viewing (www.ferruginoushawk.org and www.thermosite.com). The Department of Energy provided office space for offsite recording. Funding provided by the Woodland Park Zoo, Seattle, was used for purchase of the video equipment. The BPA line crew installed video equipment on the tower.

Ferruginous hawk data system

The data system associated with WDFW's Ferruginous hawk site is comprised of two elements: data acquisition (tower), and data collection (office). The data acquisition station includes a fixed-view camera, a wireless video line transmitter, and a solar power supply. The color camera is equipped with a 4-to-12 mm varifocal lens mounted in simple weather-resistant housing. The video transmitter is a 5.8 GHz directional system with a small directional patch antenna mounted 5.28 meters (20 feet) off the ground and in clear line-of-sight to the receiver located 0.97 km (0.7 miles) away. The solar power supply consists of a 135-watt solar panel, a 50-Ampere hour battery, and a controller that regulates the output of the solar panel, charges the battery, and provides a means of scheduling power.

The data collection station includes the wireless video link receiver, an 80 GB Digital Video Recorder (and backup DVR), and a wireless Ethernet connection to the internet. The data collection equipment is located in an office building and powered with 120 vac. The video receiver, mounted on the roof of the office building, uses a large dish antenna for reception.

2004 RESULTS

Two of three young successfully fledged from the nest platform in 2004, providing several weeks of video for later analysis, and for real-time internet viewing (Fig. 5). Details of hawk behavior, such as types of prey captured, and exact dates of events in the nesting chronology, were more clearly documented in archived images compared to what we might have been able to observe from distant observations of the nest. We experienced minor equipment problems including vibration of the camera on windy days, and

Fig. 5. Ferruginous hawk adult and young on transmission tower nest platform.

loosening of mounting screws due to high winds. In the future, we plan to continue the study with possible expansion to other nesting towers and hawks where platforms have been installed.

REFERENCES

Counts, P. 2003. Lineman and students build platforms for endangered hawks. Between the Lines, Issue No. 48. The Bonneville Power Administration, Portland Oregon.

Department of Energy. 1999. Final Hanford comprehensive land-use plan, Environmental Impact Statement (HCP EIS). Hanford Site, Richland Washington.

Fitzner, R.E. and R.L Newell. 1989. Ferruginous hawk nesting on the U.S. DOE Hanford Site. Case history of a recent invasion by transmission line. PNNL Publication, Richland, Washington.

Prairie Farm Rehabilitation Administration. 2003. Building nests for the ferruginous hawk. Agriculture and Agri-Food Canada. Ottawa, Ontario, Canada. http://www.agr.gc.ca/pfra/biodiversity/hawk_e.htm.

Richardson, S., M. Whalen, D. Demers, and R. Milner. 1999. Ferruginous hawk (*Buteo regalis*). E.M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds [Online]. Available http://wdfw.wa.gov/hab/phs/vol4/feruge.htm.

Washington Department of Fish and Wildlife. 2000. Ferruginous Hawk website. http://wdfw.wa.gov/wlm/research/raptor/ferrhawk/ferrhawk.htm.

Watson, J.W. 2002a. Ferruginous hawk recommendations and tower maintenance. Washington Department of Fish and Wildlife, Concrete, Washington, USA.

Watson, J.W. 2002b. Personal contacts. Ferruginous hawk towers. Washington Department of Fish and Wildlife, Concrete, Washington, USA.

Watson, J.W. 2003. Migration and winter ranges of ferruginous hawks from Washington. Final Report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Watson, J.W. and D.J. Pierce. 2001. Migration and winter ranges of ferruginous hawks from Washington. Annual Report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

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A Case of White-Tailed Deer Controlling the Woody Vegetation in a Power Line Right-of-Way Located in a Winter Yard

G. Jean Doucet and Eric R. Thompson

The Rigaud white-tailed deer (*Odocoileus virginianus*) yard is located approximately 100 km west of Montreal, Quebec. The yard is bisected in a north-south axis by a 120 kV transmission power line built in 1972. The power line collapsed during a major ice storm in January 1998 and was rebuilt in the summer and fall 1998. In the summer of 1998, a mechanical brush cutting treatment was completed and the vegetation was further damaged by construction activities. By October 2002 numerous woody stems were taller than 2 m. The vegetation was then treated with hand-held manual brush cutters. During the winter 2003, the right-of-way provided very little browse, but on several occasions, we observed deer browsing in the right-of-way for long periods. We formulated the hypothesis that deer browsing pressure controlled the residual woody vegetation in the right-of-way. The April 2003 and 2004 browse surveys targeted the stems of three species sought by deer: red-osier dogwood (*Cornus stolonifera*), American ash (*Fraxinus americana*) and willows (*Salix* spp.). We sampled over 200 stems of each species each spring. All these residual stems were short and most were missed during the October 2002 treatment. Browsing rates on *C. stolonifera*, *Salix* spp. and *F. americana* were respectively 97.3%, 97.3% and 84.9% in 2003, and 96.3%, 97.3% and 89.2% in 2004. These very high browsing rates indicate that when stems are short and deer density is high, deer can exert a certain control of the woody vegetation in a right-of-way in a deer yard, at least during the first winters following a vegetation control treatment.

Keywords: Activity, browse, white-tailed deer, mechanical cut, right-of-way, 120 kV power line, twig, Rigaud yard, browse rate, stem, right-of-way

INTRODUCTION

The clearing and subsequent vegetation control in power line rights-of-way located in white-tailed deer (*Odocoileus virginianus*) winter yards in Eastern Canada and the Northeast United States remain significant environmental issues (Doucet and Thompson, 2002a; Jackson and Hecklau, 1995). Over the years, Hydro-Québec has carried out a major research program on deer and rights-of-way (Doucet et al., 1997). Two transmission power lines are located in the Rigaud deer yard, a 120 kV line built in 1972 and a 735 kV line built in 1976. Studies on deer/right-of-way interactions have been conducted in the yard since 1974 and focused on habitat, behaviour, feeding strategy, and mitigation measures (Brown and Doucet, 1991; Doucet et al., 1981; Doucet et al., 1983; Doucet et al., 1987; Doucet and Brown, 2002). This paper addresses yet a different aspect of the issue of a right-of-way located in a deer yard; that of woody vegetation control by deer and related browse production management.

The recent history of the right-of-way studied is noteworthy. In January 1998, the entire 120 kV line, between the Rigaud and St-Polycarpe substations (22 km) collapsed due to a major ice storm (Doucet and Thompson, 2002a). The reconstruction activities in late summer and fall 1998 caused significant vegetation damage at tower locations and access road in the right-of-way. The impact of these vegetation disturbances were evaluated and presented in a previous paper (Doucet and Thompson, 2002a).

The right-of-way was submitted to a regular cycle of motorized treatment in July 1998 using a Hydro-Ax, model 411 mechanical brush cutter. After four

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growing seasons (1999, 2000, 2001, 2002), a mechanical treatment of all the woody vegetation using hand held brush saws was completed in the entire study section in October 2002. In winter 2003, we repeatedly observed several deer spending long periods browsing in the right-of-way, which led us to formulate the hypothesis that deer controlled the woody vegetation in the right-of-way through intensive winter browsing. This hypothesis was partly based on the assumption that deer density in the area had increased from previous years, since the number of deer crossing the right-of-way in the same direction at dusk had increased. Thus the objective of the study was to demonstrate that white-tailed deer, when present in great numbers, could control woody vegetation in the right-of-way, during the winters immediately following a vegetation control treatment.

STUDY AREA

The deer yard under study is located on the Rigaud Mountain approximately 100 km west of Montreal, QC. (45°26′N, 74°20′W), and covers an area approximately 25 km^2. In 1978, the population was estimated at 285 animals (Parent, 1978). No recent population surveys have been conducted, but when snow conditions are severe deer density in white cedar (*Thuja occidentalis*) stands can be very high. Anecdotal evidence, such as observing 115 different deer crossing the right-of-way in 45 minutes in 2003, suggested an increase in the deer population in the study area. The forest habitat near the right-of-way is characterized by deciduous or mixed stands interspersed with small islands of hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*). Other species include hawthorn (*Crataegus* spp.), sumac (*Rhus typhina*), red-osier dogwood (*Cornus stolonifera*), trembling aspen (*Populus tremuloides*), eastern cottonwood (*Populus deltoides*), balsam poplar (*Populus balsamifera*), American elm (*Ulmus americana*), ashes (*Fraxinus* spp.), choke-cherry (*Prunus virginiana*), black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*) and willows (*Salix* spp.). The forest stands attractive for deer in the Rigaud yard are those provided by white cedars, an excellent cover for wintering deer in the northeast. The section of the 120 kV right-of-way studied was approximately 1 km long, located on a gentle south-facing slope. The right-of-way is approximately 30 m wide and bisects cedar stands in the southwest section of the deeryard.

METHOD

Our goal was to test the hypothesis that the browsing rate would be practically 100% in the right-of-way during the winters 2003 and 2004 (following the October 2002 vegetation control treatment). The method consisted of a spring survey of stems and twigs of three woody species in the right-of-way in the spring 2003 and 2004. These three species were red-osier dogwood, American ash (*Fraxinus americana*), and willows. They represent species that have been browsed extensively in rights-of-way in yards over the years (Doucet et al., 1997). Browse surveys in the right-of-way were done on 24 and 25 April 2003, and on 23 and 27 April 2004. We set a minimum of 200 stems of each species to represent an adequate sample. The sampling was done in the right-of-way over a distance of approximately 1 km. Stems were surveyed where they were in the right-of-way; under the conductors, and each side in the right-of-way, but not along definite transects.

RESULTS AND DISCUSSION

The total number of stems sampled for *Cornus*, *Salix* and *Fraxinus* were respectively 204, 251, and 202 in 2003 (Table 1) and 251, 305, and 336 in 2004 (Table 2). All these stems were relatively short, with the great majority being less than 1 m in height. The number of twigs sampled on these stems, in the stratum between 50 cm and 200 cm were 1,523 for *C. stolonifera*, 1,862 for *Salix* spp. and 920 for *F. americana* in 2003 (Table 1) and 1,239, 1,682, and 759 respectively in 2004 (Table 2). In winter 2003, the browsing rate on *C. stolonifera* and *Salix* spp. was 97.3%, while the browsing rate on *F. americana* was 84.9% (Table 1). In winter 2004, browsing rates were 96.3% for *C. stolonifera*, 97.3% for *Salix* spp., and 89.2% for *F. americana* (Table 2).

In theory, the Rigaud right-of-way should have offered very little deer browse during the winter 2003, but on several occasions, we observed deer browsing in the right-of-way, and sometimes for long periods. The longest browsing bout by a given deer lasted 42 minutes. It is important to remember that the April 2003 and 2004 surveys data were collected on small stems, which escaped the mechanical (manual) cut of the vegetation in October 2002. These residual woody stems were generally the smallest stems in the right-of-way before the cut. For example, those camouflaged or hidden by stands of non-woody plants such as

Table 1. Deer browse: Rigaud deer yard winter 2003

	Stems	Twigs browsed	Twigs unbrowsed	% browsed
Cornus stolonifera	204	1,482	41	97.3
Fraxinus Americana	202	781	139	84.9
Salix (spp.)	251	1,812	50	97.3

Table 2. Deer browse: Rigaud deer yard winter 2004

	Stems	Twigs browsed	Twigs unbrowsed	% browsed
Cornus stolonifera	2514	1,194	46	96.3
Fraxinus Americana	335	798	97	89.2
Salix (spp.)	305	1,645	46	97.3

goldenrods (*Solidago* spp.), purple loosestrife (*Lythrum Salicaria*) and phragmites (*Phragmites communis*). Such small woody stems, which escaped the October 2002 control treatment, were not very visible before the snowfalls of December 2002.

At the last survey before the treatment, in April 2002, the total stem density in the Rigaud 120 kV power line right-of-way was 22,390 stems/ha, while the twig density was 88,527 twigs/ha (Doucet and Thompson, 2002b). Browse production in the right-of-way in April 2002 was dominated by red-osier dogwood, American ash, and willows, which produced 66% of twigs. These three species contributed 71% of deer diet in the right-of-way during the 2002 winter (Doucet and Thompson, 2002b). The browse rate range for the three winters (2000, 2001, 2002) before the study were as follows: 43.8%–95.6% for *C. stolonifera*, 61.7%–66.9% for *F. americana*, and 65.4%–83.5% for *Salix* spp. (Doucet and Thompson, 2002b).

White-tailed deer browse in transmission power line rights-of-way in winter. When deer density is high, this can result in a heavy browsing pressure, which at times can become excessive and cause damage to woody stems or even kill them over time. In regards to rights-of-way management, we can assume from our results that when good cover stands occur near a right-of-way, they provide shelter for a high concentration of deer. Management of the vegetation in the right-of-way could focus on deer browse production by providing browse species sought by deer in winter. Under such circumstances, our results provide evidence, albeit based on a small sample, that a heavy browsing pressure by deer could contribute to vegetation control in the right-of-way. Evidence from the literature shows that deer can have great influence on abundance of palatable browse species (Waller and Alverson, 1997).

From a management point of view, the argument is much broader that the focus (3 spp.) of this paper. For instance, trembling aspen is hardly browsed, less than 10%, by deer in winter (Doucet and Thompson, 2002b) and you could never expect deer to control trembling aspen, which sometimes can become a danger sapling for 120 kV conductors within 5–7 yrs.

In a right-of-way managed to produce browse, and where good adjacent forest cover is adequate to hold hundreds of deer, browsing in the right-of-way could maintain the stems of preferred species under 2 m of height, thus representing a form of vegetation control in the right-of-way. We suspect that such an approach, even under the form of a pilot project, would require considerable fine-tuning, especially to manipulate the plant community to produce species preferred by deer in winter. We underline the somewhat speculative nature of this argument, but it could be validated scientifically by further observations and experiments.

CONCLUSIONS

Visual observations over two winters (2003 and 2004) confirmed a high concentration of deer in the study zone during those winters. This in turn contributed a greater browsing pressure on the residual woody vegetation in the right-of-way; keeping in mind that the right-of-way offered reduced browse availability after the October 2002 vegetation control treatment.

The combination of a high deer concentration and a reduced browse availability resulted in excessive browsing rates (range 84.9%–97.3%) of the species studied. Thus, deer were practically controlling the woody vegetation of those species in the right-of-way during the 2003 and 2004 winters.

These data remain somewhat preliminary and additional experimentation and fine-tuning is required before we reach a point where we could use deer as partners in vegetation control in rights-of-way in deer yards. Under the proper set of circumstances, however, such as high population, good cover habitat in adjacent forests, and some human intervention to promote preferred browse species, it appears that deer could control a significant portion of the woody vegetation in a right-of-way through winter use.

REFERENCES

Brown, T.D. and G.J. Doucet. 1991. Temporal changes in winter diet selection by white-tailed deer in northern deer yard. Journal of Wildlife Management, 55: 361–376.

Doucet, G.J. and E.R. Thompson. 2002a. Deer browse monitoring in a reconstructed 120 kV power line right-of-way after an ice storm. Proceedings Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Calgary, AB. Elsevier Science, U.K. pp. 383–388.

Doucet, G.J. and E.R. Thompson. 2002b. Suivi du brout et de l'activité du cerf dans l'emprise à 120 kV traversant le ravage de cerfs de Virginie de Rigaud, suite à la reconstruction de la ligne après le verglas de 1998. TransÉnergie, Direction Expertise et Support Technique de Transport, Lignes, Câbles et Environnement, Montréal, QC. 13 pp.

Doucet, G.J. R.W. Stewart and K.A. Morrison. 1981. The effect of a utility right-of-way on white-tailed deer in a northern deer yard. Proceedings Second Symposium on Environmental Concerns in Rights-of-Way Management. EPRI WS-78-141, 59: 1–9.

Doucet, G.J. and D.T. Brown. 2002. Étude sur le cerf de Virginie dans l'emprise à 120 kV traversant le ravage de Rigaud: 1980–1982. Rapport final, Service Écologie biophysique, vice-présidence Environnement, Hydro-Québec. (contract: Office of Industrial Research, McGill University). TransÉnergie, Direction Support et Expertise technique de Transport, Lignes, Câbles et Environnement, Montreal, QC. Edition Novembre 2002. 85 pp.

Doucet, G.J., D.T. Brown and P. Lamothe. 1983. White-tailed deer response to conifer plantation as a mitigation measure in a power line right-of-way located in a Quebec deer yard. Proceedings Northeast Wildlife Conference, 40: 150–156.

Doucet, G.J., D.T. Brown and P. Lamothe. 1987. Deer behaviour in a power line right-of-way located in a northern wintering yard. Proceedings Fourth National Symposium on Environmental Concerns in Rights-of-Way Management. Indianapolis, IN. pp. 7–12.

Doucet, G.J., Y. Garant, M. Giguère and G. Philip de Laborie. 1997. Emprises de lignes et ravages de cerfs de Virginie – Synthèse et bilan des études. TransÉnergie, Hydro-Québec, Montréal, QC. 132 pp.

Jackson, L.W. and J. Hecklau. 1995. Construction effects of a 345 kV electric corridor on New York deer. Proceedings Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, QC. pp. 290–299.

Parent, R.. 1978. Population et habitat du ravage de cerf de Virginie du Mont-Rigaud, hiver 1977–1978. Ministère du Tourisme, Chasse et Pêche, Serv. Faune, Québec, Rapp. Tech. 28 pp.

Waller, D.M. and W.S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildlife Society Bulletin, 25: 217–226.

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Characteristics of Deciduous Woody Plant Summer Browse by White-tailed Deer on Electric Transmission Lines

Karl L. Schoeberl

Most browse studies have focused on winter browse by white-tailed deer, whereas summer browse has received relatively limited study. Although deer may browse woody vegetation more frequently in winter, summer browse may have a more substantial influence on vegetation growth and dynamics. The objective of this study was to characterize summer browsing by deer on deciduous woody plants within electric transmission line rights-of-way (ROW) in order to assess whether summer browsing by deer might be significant enough to have an impact on ROW vegetation dynamics. Browse surveys were conducted on three electric transmission lines in Dutchess County, New York from June through September 2003 in areas where white-tailed deer are quite abundant. Approximately 10 percent of the seedlings on these ROWs were browsed. Although desirable (slow, low growing) seedling species dominated the ROWs, undesirable (fast, tall growing) species were more frequently browsed. It was also determined that most of the browse occurred in the border zone rather than the wire zone, thereby limiting some of the benefits to utility vegetation management that may be produced by deer browsing.

Keywords: White-tailed deer, summer browse, vegetation management, transmission line, ROW

INTRODUCTION

What is the extent of deer browsing on electric transmission line rights-of-way (ROW)? What species of shrubs and trees are they browsing and does browse contribute to the efforts of utility vegetation management programs? This paper presents the preliminary results of research that was focused on those questions.

White-tailed deer (*Odocoileus virginianus*) are quite abundant in the Hudson Valley Region of New York State (NYSDEC, 2003). They are voracious browsers and can significantly impact the growth of woody vegetation where browsing is excessive (Alverson et al., 1988). In most instances deer browse is considered to produce the negative effect of limiting plant growth and biodiversity in natural habitats; however, in some situations excessive browsing may be beneficial, such as in areas where vegetation growth must be intensively managed. One such area is that of the electric transmission line ROW.

To the extent that factors such as deer browsing may help to control vegetation growth on ROWs, some benefit will be realized in terms of reduced utility maintenance costs and reduced volume of herbicides that must be used. Any factors that may contribute to the reduced dependence on herbicides must be considered as a positive influence in ROW management and consistent with Integrated Vegetation Management (IVM) principles.

Previous studies have looked at the value of ROWs to wildlife (Bramble and Byrnes, 1979), and many studies have looked at the effects of transmission lines (construction and maintenance) on deer (Doucet and Thompson, 2002; Jackson and Hecklau, 1995) but few have looked at the effect of deer on the ROW. Also, most browse studies have focused on winter browse, while only a few have looked at summer browse (Bramble and Goddard, 1953) or considered the effects it may have on plant growth from a ROW vegetation management perspective. In their long-term study of ROW vegetation dynamics (Canham et al., 1999)

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Fig. 1. Study area location.

determined that browsing by white-tailed deer can significantly reduce the rate of tree invasion on ROWs. Their studies also concluded that the timing and intensity of browse is a major factor and that in particular, summer browsing has significant effects on seedling growth and survival. They suggested that although summer browsing is less common than winter browsing, it may be more important as a mechanism for inhibiting tree invasion on ROWs.

Objectives

Objectives of this study were to:

- Characterize deer browsing activities on ROW woody vegetation in summer;
- Compare the amount of browse on what utility vegetation managers consider "desirables" vs. "undesirables" (generally low, slow growing species vs. tall, fast growing species) to determine what is more frequently browsed;
- Identify spatial patterns of browsing within the ROW.

It was anticipated that the following possible scenarios might exist: (1) deer are primarily browsing tall growing species (undesirables), or (2) deer are primarily browsing low-growing species (desirables). Scenario 1 would provide a positive effect on ROW management because the growth of those tall growing species that might ultimately interfere with the wires would likely be limited. In scenario 2 there are two possible consequences. It is possible that browse could either limit the growth of those low-growing species (desirables), which would not provide a positive effect on utility vegetation management where the goal is to establish stable low-growing plant communities on the ROW. Or it is possible that browse could have the effect of creating a denser and higher percent of cover among those low-growing shrubs. This study did not attempt to identify those possible effects of browsing. The focus was to simply characterize the amount of browse that is occurring on "desirables" vs. "undesirables" within ROWs.

METHODS

Study site selection

The transmission lines surveyed are in Dutchess County, which is within the Hudson Valley Region of New York State (Fig. 1). Study sites were selected in areas of known high deer population density. Based on New York State Department of Environmental Conservation (NYSDEC) buck harvest data from 1998–2000, it is estimated that the deer population in the area of study is approximately 34–48 per square mile. The average deer population density in Dutchess County overall is 25–29 per square mile. Deer population data were compared with Central Hudson Gas & Electric Corporation's electric transmission lines to identify general areas of study. Within those, sections of transmission line ROW that traverse forested areas were selected because prior research (Canham et al., 1999) suggested that deer browsing would be most significant where ROWs intersected heavily forested areas, and because these are the areas where ROW vegetation management is generally the most challenging. Finally, only transmission lines that had not been treated (sprayed or cut) in at least three years were surveyed. It is acknowledged that this is a non-random sampling

Fig. 2. Typical ROW in study area.

Table 1. Summary of transmission line characteristics and survey data

Characteristic	E line	MR line	Q line
Elevation Range (ft above MSL)	300′–1200′	200′–600′	200′–400′
General Direction of Line Orientation	Southwest to Northeast	West to East	North–South
Approximate Total Line Length (meters)	32000	11000	34000
Approximate ROW Width (meters)	50	33	33
Approximate Length of Line traversing forested areas (meters)	14530	8040	15900
% of Transmission Line through forested areas	45.4%	73.1%	46.8%
Approximate Length of Line Surveyed (meters)	670	650	370
% of Total Line surveyed	2.1%	5.9%	1.1%
% of forested areas surveyed	4.6%	8.1%	2.3%
Date Range for Surveys	6/23/03–8/9/03	8/12/03–9/4/03	9/9/03–9/17/03
# Days surveys conducted	9	6	4

method, but the goal was to observe and characterize as much browsing as possible in order to get a fair representation of what species are being browsed within the ROW. In areas where deer are less abundant it is possible that the species utilized for browse will differ. Figure 2 provides an example of typical ROW within the study area.

Field methods/data collection

Browse surveys were conducted from June 23rd 2003 to September 17, 2003. Table 1 presents a summary of the key characteristics for each line.

Surveys were conducted by walking each selected ROW segment, stopping at approximately 100 meter intervals. A Trimble Pathfinder Pocket GPS receiver used in tandem with ArcPad software (from Earth Systems Research Institute-ESRI) on a handheld Hewlett-Packard Jornada Pocket PC were used to maintain position on t he ROW and to collect all data. A plot was established approximately 10 m wide across the entire width of the ROW at each of the 100 meter interval locations. To facilitate subsequent data analysis, each plot was identified as E1-1, E1-2, Q1-1, Q1-2, etc. Each plot was thoroughly searched for individual deciduous woody tree and shrub seedlings 0.5–2.0 meters in height. All observed seedlings were identified and counted to determine the total number of seedlings and the dominant species in each plot. For each plot, the total number of seedlings and the dominant species were then recorded.

All seedlings with observable browse were then revisited for additional data collection. It was assumed that all observed browse was done by white-tailed deer because browse was only counted for those seedlings greater than 0.5 m (and less than 2.0 m). Since this survey was done in the summer (i.e. no snow) it is not likely that any small mammals could have browsed any of the seedlings within the scope of the survey. Based on the fact that shrub seedlings examined for this study were small enough (less than two meters),

Fig. 3. "Severe" browse on a black birch seedling.

Table 2. Summary of seedling data within plots

	E line	MR line	Q line
# Plots	67	65	37
Total # seedlings observed	824	489	367
Avg # seedlings/plot	12.30	7.52	9.92
Average # seedlings/acre	357	327	431
# Different Species identified as Dominant Species	15	8	9
The 3 Most Frequently Dominant Species in Plots (# Plot Occurrences as Dominant)	Honeysuckle (12)/Black birch (6)/Gray dogwood (4)	Honeysuckle (35)/Black birch (6)/Scrub oak & Gray birch (4)	Black birch (9)/Honeysuckle (6)/ Scrub oak (6)
# Plots w/Desirable Species identified as dominant/% of total	27/40.3%	45/69.2%	16/43.2%
# Plots w/Undesirable Species identified as dominant/% of total	19/28.4%	11/16.9%	14/37.8%
# Plots with no seedlings/% of total	21/31.3%	9/13.8%	7/18.9%

the extent of browse was characterized in the same manner for both shrub and tree seedlings. For each browsed seedling observed, the following data were collected (also using ArcPad and the GPS receiver):

- Species;
- Height (cm);
- Browse Extent, defined as follows (adapted from categories used by Aldous, 1944): (Fig. 3 shows an example of "severe" browse on a black birch seedling);
- ***Light*** = some evidence of browsing on lateral limbs, but no browse on terminal;
- ***Moderate*** = significant browsing on lateral limbs **or** some evidence of browsing on terminal;
- ***Severe*** = significant browsing on lateral limbs **and/or** significant browsing on terminal;
- Percent shrub cover around each browsed seedling (based on visual estimate);
- Distance of browsed seedling from ROW centerline (meters).

For subsequent data analysis, "desirable" species were differentiated from "undesirable" species based on species lists that have been developed by New York utility companies and the New York State Public Service Commission for this region.

RESULTS

Table 2 provides a summary of seedling data within the plots. A total of 169 plots were surveyed for browse among the three transmission lines. 1,680 seedlings were observed within the plots, which is an average of approximately 10 seedlings per plot or 370 per acre. Seedling density ranged from an average of 327/acre on the MR Line to 431/acre on the Q Line. The average number of seedlings per plot was relatively consistent among lines; however, those numbers may be somewhat biased because some plots had a very high number of seedlings (i.e. several plots were dominated by dense stands of sweet fern). Honeysuckle was most frequently identified as the dominant species within the plots.

Whereas all browsed seedlings were subsequently identified, among the total seedlings within the plot only the dominant species was identified and recorded. Thus, twenty-three species were recorded during the study (Table 3). Ten of these species were desirables and thirteen were undesirables.

Although there was not a large difference, it seems that desirable species were more frequently identified as the dominant species within plots (Fig. 4). On the E Line and the Q Line desirable species represented 41% and 43%, respectively of the seedling species identified as dominant within the plots. On the MR Line, the difference was more striking where 69% of the plots had a desirable species identified as being dominant. Undesirable species were identified as dominant in 28% of the plots on the E Line, 38% on the Q Line, and only 17% of the MR Line plots. Plots with no seedlings were found 31% of the time on the E Line, 19% on the Q Line, and 14% on the MR Line.

Table 3. Species List

Desirables	Undesirables
Honeysuckle (*Lonicera spp*)	Red maple (*Acer rubrum*)
Apple (*Malus spp*)	Red oak (*Quercus rubra*)
Arrowwood (*Viburnum dentatum*)	Cottonwood (*Populus deltoids*)
Gray dogwood (*Cornus racemosa*)	White oak (*Quercus alba*)
Viburnum spp	Black birch (*Betula lenta*)
Blackhaw (*Viburnum prunifolium*)	Ailanthus (*Ailanthus altissima*)
Blueberry (*Vaccinium spp*)	Quaking aspen (*Populus tremuloides*)
Juniper (*Juniperus communis*)	Black locust (*Robinia pseudoacacia*)
Sweet fern (*Comptonia peregrine*)	Gray birch (*Betula populifolia*)
Scrub oak (*Quercus ilicifolia*)	American elm (*Ulmus americana*)
	Sassafras (*Sassafras albidum*)
	Black cherry (*Prunus serotina*)
	American hornbeam (*Carpinus caroliniana*)

Table 4 provides a summary of the browse data. One hundred sixty-one (161) browsed seedlings were observed among all plots on all transmission lines. There was an average of 45 browsed seedlings per acre for all lines (an average seedling browse percentage of 9.6% when expressed as # browsed / # available). The lowest browse percentage was seen on the E Line where

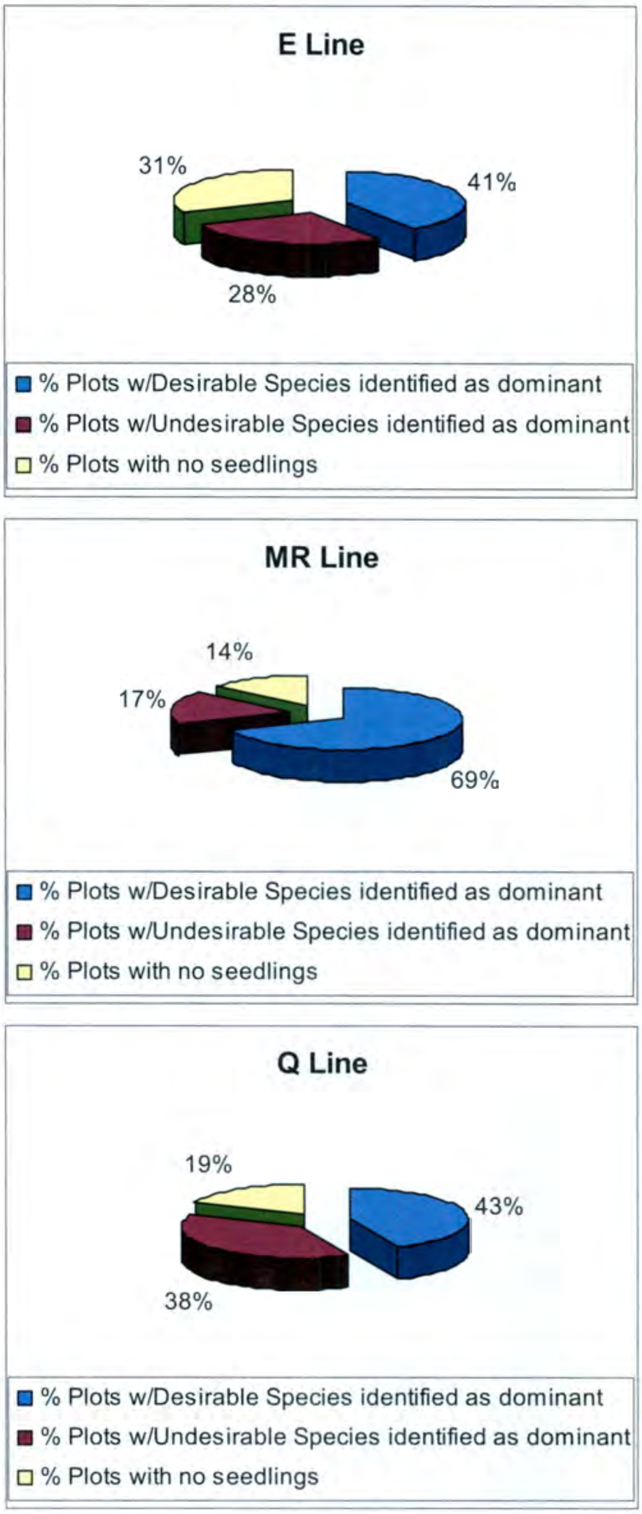

Fig. 4. Comparison of % desirable vs. undesirable species within plots for each line.

Table 4. Summary of browsed seedling data

# Different species observed w/evidence of browse	E line 9	MR line 8	Q line 9
The 3 most frequently browsed species (# Browsed Seedlings)	Red oak (7)/Honeysuckle (2)/ White oak (2)/Arrowwood (2)/ Gray dogwood (2)	Black birch (40)/ Gray birch (14)/ Arrowwood (9)	Black birch (34)/Gray birch (16)/Sweet fern & Scrub oak (3)
Total # of browsed seedlings observed	19	79	63
Browse Rate (# Seedlings Browsed/# Seedlings Observed)	2.3%	16.2%	17.2%
Avg # Browsed Seedlings per Plot	0.28	1.22	1.70
# Browsed Seedlings per acre	8	53	74
# Browsed ***Desirable*** Seedling Individuals/% of total	7/36.8%	21/26.6%	7/11.1%
# Browsed ***Undesirable*** Seedling Individuals/% of total	12/63.2%	58/73.4%	56/88.9%
Avg Height of browsed seedlings (cm)	101	96	102
Height Range for Browsed seedlings (cm)	50–200	50–190	50–200
Avg % Shrub Cover surrounding browsed seedlings	23.68	19	22
Range of % Shrub Cover for browsed seedlings	0–80	0–80	0–75
Avg Distance from Centerline for browsed seedlings (m)	4	5	4
Range of Distance from Centerline for browsed seedlings (m)	0–10	0–10	0–8
% Browsed Seedlings in Wire Zone	31.6%	20.3%	41.3%
% Browsed Seedlings in Border Zone	68.4%	79.7%	58.7%
Conductor Spacing	14 feet	14 feet	12 feet
%'s of Browse Extent for all Browsed seedlings	$s = 7$ (36.8%) $m = 9$ (47.4%) $l = 3$ (15.8%)	$s = 54$ (68.4%) $m = 22$ (27.8%) $l = 3$ (3.8%)	$s = 37$ (47.6%) $m = 24$ (38.1%) $l = 2$ (3.3%)

there 2.3% of seedlings were browsed or 8 seedlings per acre, to a high on the Q Line of 17.2%, or 74/acre.

Black birch, gray birch, and arrowwood (in that order) were the most frequently browsed species. Overall, undesirable species accounted for approximately 78% of the 161 browsed seedlings observed. Undesirable species accounted for 63% of the browsed seedlings on the E Line, 89% on the Q Line, and 73% on the MR Line (Fig. 5).

In order to simplify the analysis of spatial aspect within the ROW, measurements of "distance from centerline" were converted to either "wire zone" or "border zone." Based on the actual plan & profile drawings of the transmission lines studied, it was determined that the conductor spacing was approximately 12–14 feet (~4–5 meters). Splitting the maximum dimension of wire spacing (5 meters) results in a distance of approximately 2.5 meters on either side of centerline. Therefore, all browsed seedlings recorded from 0 to 2.5 meters were considered to be within the wire zone, and seedlings recorded as greater than 2.5 meters were considered to be in the border zone (Table 4). As shown in Fig. 6, the majority of browsed seedlings were located in the border zone (68% of browsed seedlings on the E Line, 59% on the Q Line, and 80% on the MR Line).

CONCLUSIONS

The results of this study indicate that approximately 10% of the seedlings existing on these ROWs were browsed by white-tailed deer in summer. It also seems that browse by white-tailed deer generally favored undesirable species. This was particularly evident on the Q Line, where nearly 90% of the browsed seedlings were undesirables. However, from a vegetation management perspective, it is unfortunate that most of the browse seems to be in the border zone where it provides somewhat less benefit. And although there is certainly some summer browse occurring, it is not likely that summer browse alone is having significant effects on the vegetation dynamics on ROWs.

White-tailed deer can have a significant effect on vegetation dynamics. Other studies have demonstrated that deer browsing can be a significant factor affecting natural succession. Stromayer and Warren (1997) assert that overabundant deer herds may be "creating alternate stable states" of vegetation in our forests. On ROWs this might be viewed as a positive result, as ROW management attempts to hold natural succession in check. They also suggest that the effects of overabundant deer "will intensify in the future," thus it is certainly possible that deer may play some role in ROW vegetation management.

Honeysuckle (a desirable species) was frequently a dominant species on all of these ROWs and based on this survey, it appeared that there was very little browse on honeysuckle. From a vegetation management perspective, it is good to see that it is not heavily browsed and it is possible that this is one of the factors that has helped it to become so well established on

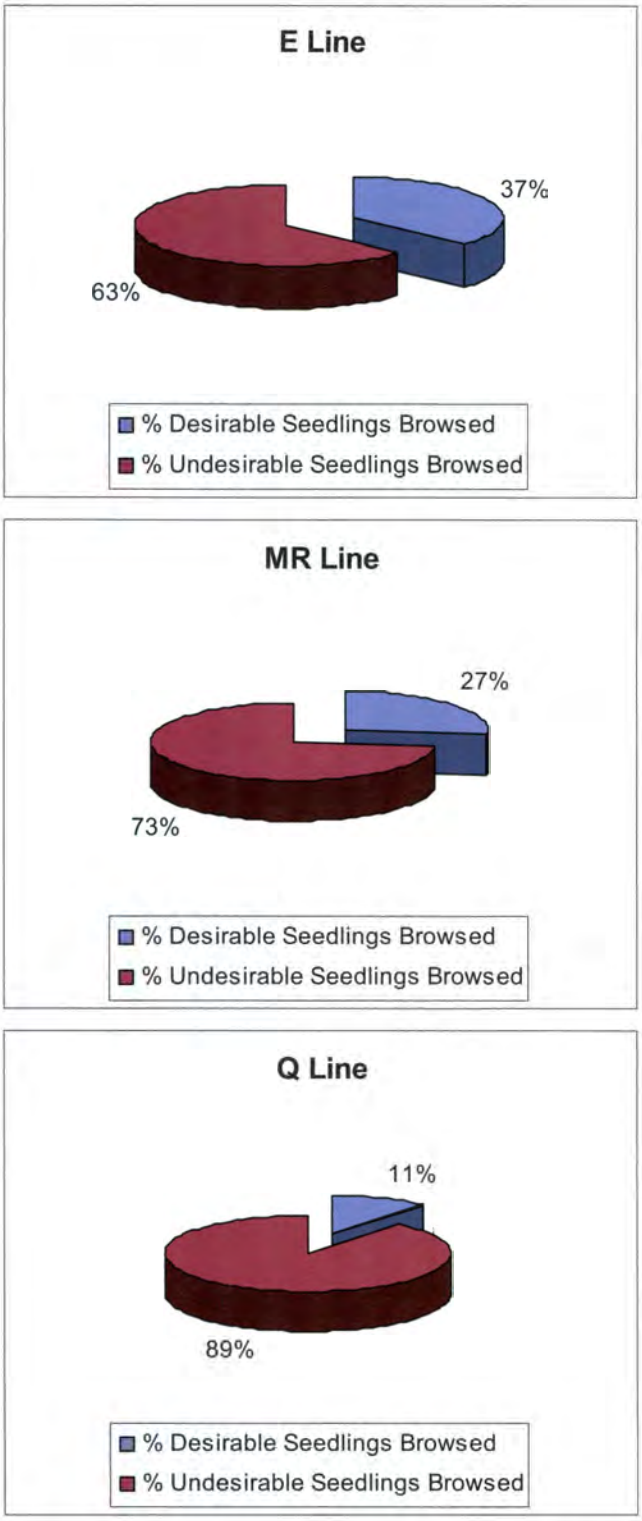

Fig. 5. Comparison of % desirable vs. undesirable species among browsed seedlings for each line.

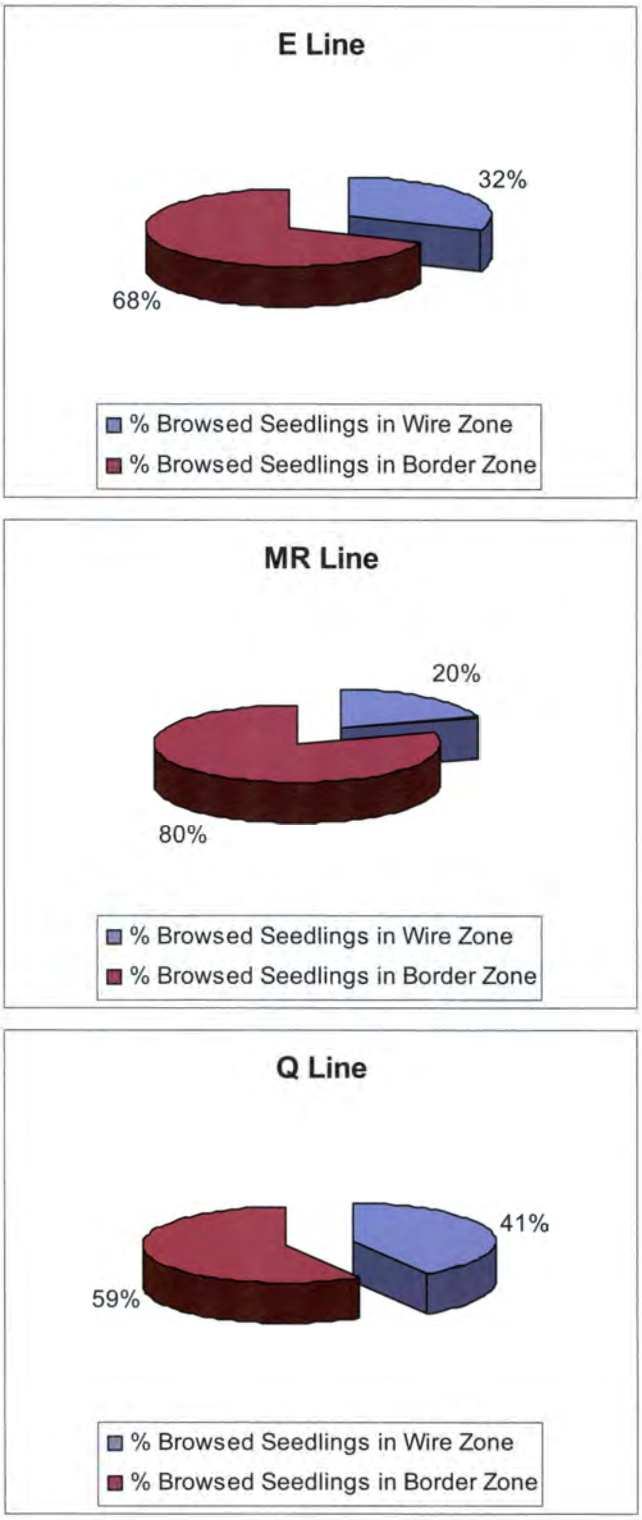

Fig. 6. All browsed seedlings in wire zone vs. border zone for each line.

these ROWs where deer are abundant – perhaps deer have had some influence in giving honeysuckle a competitive edge by browsing other species.

For future studies of summer browse it is suggested that surveys like this need only be done in late August – early September to ensure capture of all summer browse.

REFERENCES

Aldous, Shaler. 1944. A Deer Browse Survey Method. Journal of Mammalogy. Vol 25, no. 2, pp. 130–136

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forest Too Deer: Edge Effects in Northern Wisconsin. Conservation Biology. 2(4). pp. 348–358.

Bramble, W.C. and W.R. Byrnes. 1979. Evaluation of the Wildlife Habitat Values of Rights-of-Way. Journal of Wildlife Management. 43(3). 642–649.

Bramble, W.C. and M.K. Goddard. 1953. Seasonal Browsing of Woody Plants by White-tailed Deer in the Ridge and Valley Section of Central Pennsylvania. Journal of Forestry. November 1953. pp. 815–819.

Canham, C.D., A.R. Berkowitz, J.B. McAninch, M.J. McDonnell, and R.S. Ostfeld. 1999. Vegetation Dynamics Along Utility Rights-of-Way: Factors Affecting the Ability of Shrub and Herbaceous Communities to Resist Invasion by Trees; EPRI, Palo Alto, CA; Central Hudson Gas and Electric Corporation; Empire State Electric Energy Research Corporation (ESEERCO): 1999. TR-113377.

Doucet, G.J. and E.R. Thompson. 2002. Deer Browse Monitoring in a Reconstructed 120 kV Powerline Right-of-Way after an Ice Storm. In: Proceedings Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. pp. 383–387.

New York State Department of Environmental Conservation (NYSDEC). 2003. Deer harvest data from 1998–2000 provide by NYSDEC Region 3.

Jackson, L.W. and J. Hecklau. 1995. Construction effects of a 345 kV electric corridor on New York deer. In: Proceedings Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. pp. 290–299.

Stromayer, K.A. and R.J. Warren. 1997. Are Overabundant deer herds in the eastern United States creating alternate stable states in forest plant communities? Wildlife Society Bulletin. 25(2): 227–234.

BIOGRAPHICAL SKETCH

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Avian Shrub Land Management and Shrub Land Nesting Success

J.L. Confer, T. Hauck, M.-E. Silvia, and V. Frary

The availability of shrub land habitat is declining in the northeastern United States due to reforestation on abandoned farmland. This has resulted in a decrease in shrub land birds across the region. Utilities maintain more acreage of managed shrub lands on power line rights-of-way (ROW) than is provided by all other sources combined in eastern United States. In Sterling Forest State Park, NY we assessed the effect of thinning shrub density on breeding bird density along distribution lines. Six areas of dense vegetation were chosen for management. Each area was cut and stem-treated with herbicides. Two bird counts were taken in a pretreatment year and in each of three subsequent years to determine the number of species and individuals in each of the six managed areas. Data compiled using spot-mapping showed an average annual increase of 21% in the number of species and 27% increase in the number of individuals. These results demonstrate that the density and diversity of shrub land birds on ROW can be altered by different management practices.

Keywords: Shrub lands, avian diversity, habitat management, right-of-way

PERSPECTIVE ON SHRUB LAND HABITATS AND UTILITY RIGHTS-OF-WAY

Shrub land birds are rapidly declining throughout much of the United States. The federal Breeding Bird Survey (Sauer et al., 2004) shows that thirteen shrub land species have significant negative trends while only four have significant positive trends in northeastern United States (Fig. 1). Much of the decline of shrub land birds is due to the loss of habitat. Early in the last century, abandoned farmland in northeastern United States provided millions of acres of shrub land habitat. Reforestation, however, has converted almost all of those shrub lands into forest. Anthropogenic shrub land will continue to decline as the rate of abandonment of the remaining farmland continues to decline. In New York, we have also lost over a million acres of pre-settlement shrub land habitat largely due to draining beaver wetlands and fire-suppression in fire-maintained ecosystems (Confer and Pascoe, 2003).

In the northeastern United States, utilities are the only group or organization that manages significant amounts of shrub land habitat. In New York, which is typical of the northeast, only about 15,000 acres of shrub land habitat is managed by all federal, state and non-governmental organizations, excepting utilities. In striking contrast, New York electric utilities manage about 125,000 acres of shrub land habitat under high voltage lines alone plus a similar acreage under distribution lines. Rights-of-way (ROW) are by far the major source of managed shrub land habitat in the Northeast and will become increasingly important for the conservation of shrub land birds. Thus, conservation efforts would be particularly enhanced if ROW were managed in a way that is optimal for shrub land species as indicated by the avian community.

ANALYSES OF THE AVIAN COMMUNITY DENSITY AND NESTING SUCCESS ON ROW

During 2002, New York State Electric and Gas and Orange and Rockland Utilities supported our studies of the distribution and nesting success of birds on ROW in Tompkins and Orange Counties. During 2003,

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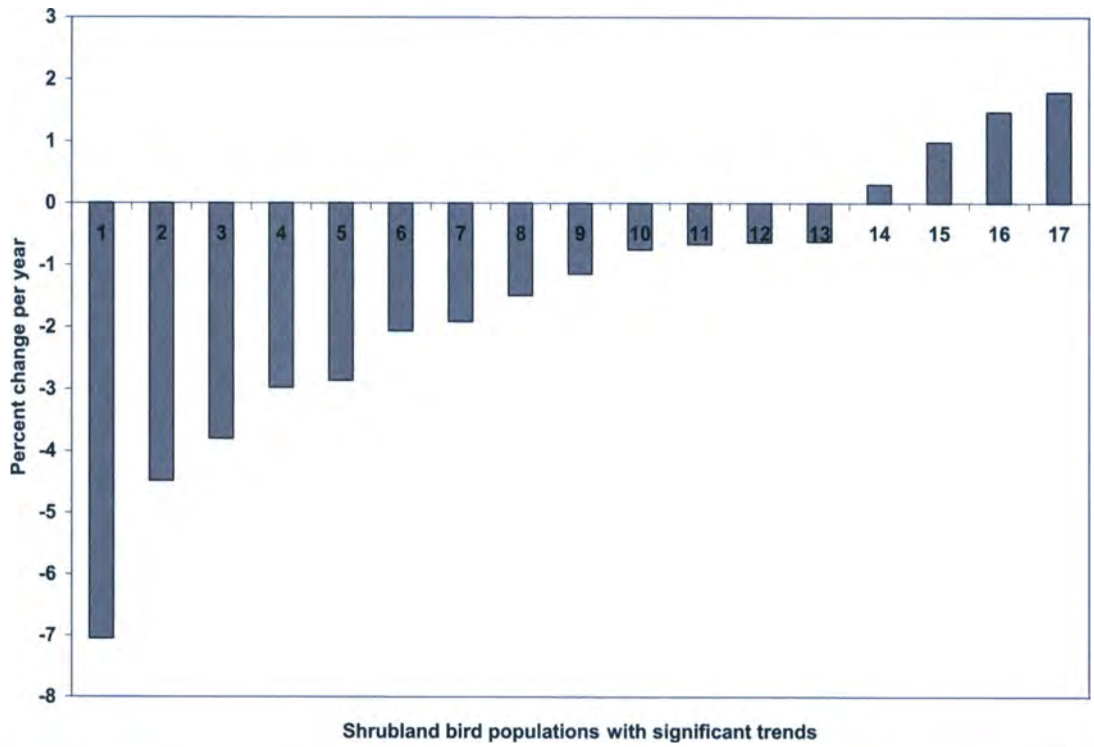

Species with statistically significant population declines are: 1) golden-winged warbler (*Vermivora chrysoptera*), 2) northern bobwhite (*Colinus virginianus*), 3) field sparrow (*Spizella pusilla*), 4) eastern towhee (*Pipilo erythrophthalmus*), 5) brown thrasher (*Toxostoma rufum*), 6) yellow-breasted chat (*Icteria virens*), 7) white-throated sparrow (*Zonotrichia leucophrys*), 8) prairie warbler (*Dendroica discolor*), 9) song sparrow (*Melospiza melodia*), 10) indigo bunting (*Passerina cyanea*), 11) house wren (*Troglodytes aedon*), 12) American goldfinch (*Carduelis tristis*), 13) chestnut-sided warbler (*Dendrioca pensylvanica*), and species with significant population increases are: 14) northern cardinal (*Cardinalis cardinalis*), 15) willow-alder flycatcher (*Empidonax traillii-alnorum*), 16) mourning warbler (*Oporornis formosus*), 17) Carolina wren (*Thryothorus ludovicianus*).

Fig. 1. Population changes for shrub land birds of northeastern United States as estimated by the federal Breeding Bird Survey for 1966–2003.

studies were continued in Orange County with support from the Biodiversity Research Institute of the New York State Museum and a State Wildlife Grant, administered by the New York State Department of Environmental Conservation. Results from both studies are described here.

Avian diversity on ROW in Tompkins and Orange Counties, New York

Nests of 12 species were found on ROW in Tompkins County (Table 1). At least another 15 species nested on or near the ROW and foraged along the forest-ROW ecotone and onto the ROW. These include Wild Turkey (*Meleagris gallopavo*), American Crow (*Corvus branchyrhyncos*) and Blue Jay (*Cyanocitta cristata*), Black-capped Chickadee (*Poecile atricapillus*), Tufted Titmouse (*Baeolophus bicolor*) and several species each of woodpeckers, blackbirds and swallows.

Bird diversity on ROW of New York State Electric and Gas in Tompkins County and ROW of Orange and Rockland Utilities in Orange County are similar. Quantitative analyses of observations on ROW in Orange County, which were more extensive than in Tompkins County, show that ROW support a high density and diversity of shrub land birds, many of which are declining throughout New York and northeastern United States (Table 2). As an extreme example, the abundance of golden-winged warblers and prairie warblers on ROW in Orange County is about 200 times greater than on average throughout the State.

Table 1. Species with known nests on ROW of New York State Electric and Gas, 2002

Species		Number of nests
Gray Catbird	(*Dumatella carolinensis*)	15
Song Sparrow	(*Melospiza melodia*)	15
Yellow Warbler	(*Dendroica petechia*)	12
American Robin	(*Turdus migratorius*)	11
Common Yellowthroat	(*Geothlypis trichas*)	4
Chestnut-sided Warbler	(*Dendroica pensylvanica*)	3
Eastern Towhee	(*Pipilo erythrophthalmus*)	3
Cedar Waxwing	(*Bombycilla cedrorum*)	2
Field Sparrow	(*Spizella pusilla*)	2
Mourning Dove	(*Zenaida macroura*)	1
Blue-winged Warbler	(*Vermivora pinus*)	1
Prairie Warbler	(*Dendroica discolor*)	1

Table 2. Abundance and population trends for species in ROW of Orange and Rockland Utilities within Sterling Forest State Park in southern New York

Species	No./Point count Orange & Rockland ROW in Sterling Forest SP	Point count ratio Sterling Forest SP/US Breeding Bird Survey	Population trends New York
Prairie Warbler	1.5	226	5.7
Gray Catbird	1.2	4.9	−0.1
Eastern Towhee	1.0	11	−6.0
Common Yellowthroat	0.90	2.3	−0.1
Yellow Warbler	0.89	3.0	0.3
Blue-winged Warbler	0.71	53	1.6
Golden-winged Warbler	0.68	201	−5.6
Field Sparrow	0.58	5.4	−4.1
American Goldfinch	0.53	1.4	−1.5
Black-and-white Warbler	0.47	16	−1.8
Northern Oriole	0.47	3.1	−0.8
Brown-headed Cowbird	0.42	2.3	−2.3
Chestnut-sided Warbler	0.42	3.5	−0.8
American Redstart	0.32	3.0	−1.4
Indigo Bunting	0.32	2.9	0.1
Rose-breasted Grosbeak	0.24	2.6	−1.0

Listed species utilized the ROW as part or all of their nesting territory and occurred on nearly 25% or more of 38 point counts taken in May–June of 1998–99. The ratio is derived from the mean number of individuals per point count in ROW managed by selective herbicide application compared to the mean number per point count for the federal Breeding Bird Survey (BBS) from 1966–'98 for New York. Population trends are derived from BBS data for New York.

Table 3. Nesting success on ROW in 2001–2003 in New York with emphasis on the rapidly declining golden-winged and blue-winged warblers (*Vermivora chrysoptera* and *V. pinus*)

Year – location	No. Vermivora nests	Vermivora nesting success	No. nests, other species	Other species, nesting success	Overall nesting success
2001 – Orange Co., NY	13	62%	43	53%	55%
2002 – Orange Co., NY	12	33%	26	27%	29%
2002 – Tompkins Co., NY	1	0%	64	44%	43%
2003 – Orange Co., NY	20	45%	6	66%	50%

NESTING SUCCESS ON ROW

Studies of nesting success on ROW during 2000 were supported by Orange and Rockland Utilities, National Grid USA, and Central Maine Power. These results were described earlier (Confer, 2002) and are summarized here for comparison. The average nesting success for 56 nests on 8 ROW in Massachusetts, Maine and New York was 51% ($n = 56$). In largely forested landscapes, the success rates for nests on ROW and in forests adjacent to these ROW varied among states from 51% to 69% (sum $n = 131$). This compares favorably to an average nesting success of 49% based on a review of data from over 40,000 nests (Nice, 1957). Nesting success of 49% and above is sufficient to sustain bird populations.

Studies of nesting success in 2001 through 2003 were supported by Orange and Rockland Utilities and New York State Electric and Gas. Nesting success on ROW in Orange County in 2001 and 2003 was 55% and 50%, respectively (Table 3). Nesting success, however, was very poor in 2002 (Table 3). The proportion of nests for all species that fledged young was 29% ($n = 38$) in Orange County and 43% ($n = 65$) in Tompkins County. The most rapidly declining avian species in these nesting surveys are the golden-winged and blue-winged warblers and the proportion of nests ($n = 12$) for these two species that fledged young in Orange County was only 33%. Bird populations could not sustain themselves if these results were typical for most years.

During 2002, the abundance of eastern chipmunk (*Tamias striatus*) exceeded previous high densities. Although primarily a consumer of fruits and nuts, the chipmunk is a well-documented predator on eggs and nestlings. Holmes et al. (1992) report that "At Hubbard Brook, annual nesting success has varied 20–74% (n = 9 years) (Sherry and Holmes 1992) for American Redstarts (*Setophaga ruticilla*) and 46–79% (n = 12 years) for Black-throated Blue Warblers (*Dendroica caerulescens*) (Holmes et al., 1992; 1996). Such variation in nest survival among years is related to differences in the abundance of major nest predators (e.g. Eastern Chipmunks, and Red Squirrels, *Tamiasciurus hudsonicus*), which in turn is related to the intermittent but highly synchronous production of seeds by forest trees (Ostfeld and Keesing, 2000)." In some years, oaks produce an exceptionally large number of acorns. In so-called mast years, chipmunks store an abundance of food for winter, survive well and have large spring broods. The spring after a mast year, chipmunk abundance can be extremely high, leading to high predation on bird nests. This illustrates a trophic cascade whereby pulsatile changes in food abundance at one trophic level, such as the acorns, alter the species abundance at another trophic level, such as chipmunks, which in turn produces unusual affects on a third trophic level, the nesting success of birds.

A mast year occurred throughout much of New York and adjacent Pennsylvania in the fall of 2001. Eastern chipmunk populations were unusually high during the following nesting season. For example, I saw seven chipmunks at once on ROW of Orange and Rockland Utilities and similar high abundance occurred in Tompkins County. Another ecologist studying golden-winged warblers in Pennsylvania informed me that all 11 *Vermivora* nests observed in his survey in 2002 were destroyed, which he attributed to high chipmunk predation (C. Rossell, Jr., pers. com.).

AVIAN COMMUNITY RESPONSE TO REDUCED SHRUB DENSITY

In 1999, Orange and Rockland Utilities initiated an experimental reduction of shrub lands on segments of ROW that had very dense shrub cover to determine if this might enhance the density of nesting birds. Results from this 4-year study have implications about optimal management for the avian community on utility ROW throughout the northeast.

Site attributes

Previous surveys have shown that a few shrub land bird species prefer dense shrubs but that the majority of shrub land species prefer areas with about 50% herb cover (Confer and Pascoe, 2003). Shrub reduction in areas with very dense shrub cover would allow herb cover to increase, favoring several species, including blue-winged and golden-winged warblers, field sparrow, and song sparrows. All six sites selected for management had dense shrub growth throughout their length. Honeysuckle spp. (*Lonicera* spp.) and Barberry spp. (*Berberus* spp.) were most common at most sites while mountain laurel (*Kalmia latifolia*) dominated at one site. Prior to shrub removal, the ground under the dense shrubs was almost devoid of herbs and newly exposed ground had very little herbaceous growth in the first spring after removal of the shrubs in fall. Five of the sites were surrounded by typical forest vegetation. The sixth site became partially submerged by water from an expanding beaver pond and is omitted from further consideration in this paper. All sites were within Sterling Forest State Park, NY. Two sites were under high voltage lines, while four were under distribution lines. Sites varied between 200 and 400 m in length and 15 to 75 m in width, providing a wide variety of spatial conditions. Bird abundance varied among the sites so that results are presented as relative change within a site. Management began in the fall of 1999 when shrubs were cut and stem treated to ensure their removal.

Survey technique

Two, 20-min surveys were conducted at each site for each of four years. Surveys were completed before 10 AM because birds are more active in the morning. During the surveys, each individual bird was recorded on a site map as a "spot" accompanied by its species code. Maps of replicate counts for each site for each year were compared to distinguish two counts of the same individual bird, indicated by two spots that are very close, from observations of two different birds of the same species, indicated by spots that are far apart on the map. This process takes advantage of the behavior of breeding birds whereby individual birds usually stay within their own breeding territory. The number of individuals and the number of species were tabulated after compiling the duplicate counts for each site for each year.

All bird surveys were conducted in late May and early June. Counts in 1999 served as a pre-treatment control. The birds present initially favored or at least tolerated dense shrub lands. In spring 2000, herbaceous growth had barely started to grow in those areas covered by dense shrubs in the previous fall. Surveys in the spring of 2001 and 2002 occurred after a period of moderate growth of herbaceous vegetation.

RESULTS FROM REDUCTION OF SHRUB DENSITY

Management of the ROW resulted in both an increase in number of species and number of individuals (Figs. 2 and 3). From 1999 to 2000, 2001 and 2002, the average number of species per site increased from 6 to 10 to 12 to 14. The results were consistent among all five sites, suggesting there were no site-specific factors, such as ROW width, that accounted for the response. The strong response for the first spring after the fall treatment (Table 4) is surprising. At the time of the survey in May and early June of the first spring after fall treatment, herbs showed a very minimal response to the removal of shrubs in the preceding fall. The new species responded to the openness of the area or the absence of shrubs and not to growth of new herb cover. The sum of the number of species for all sites increased by 130% during this study (Table 4).

At each site, the percent increase in the number of individuals and the number of species showed a large

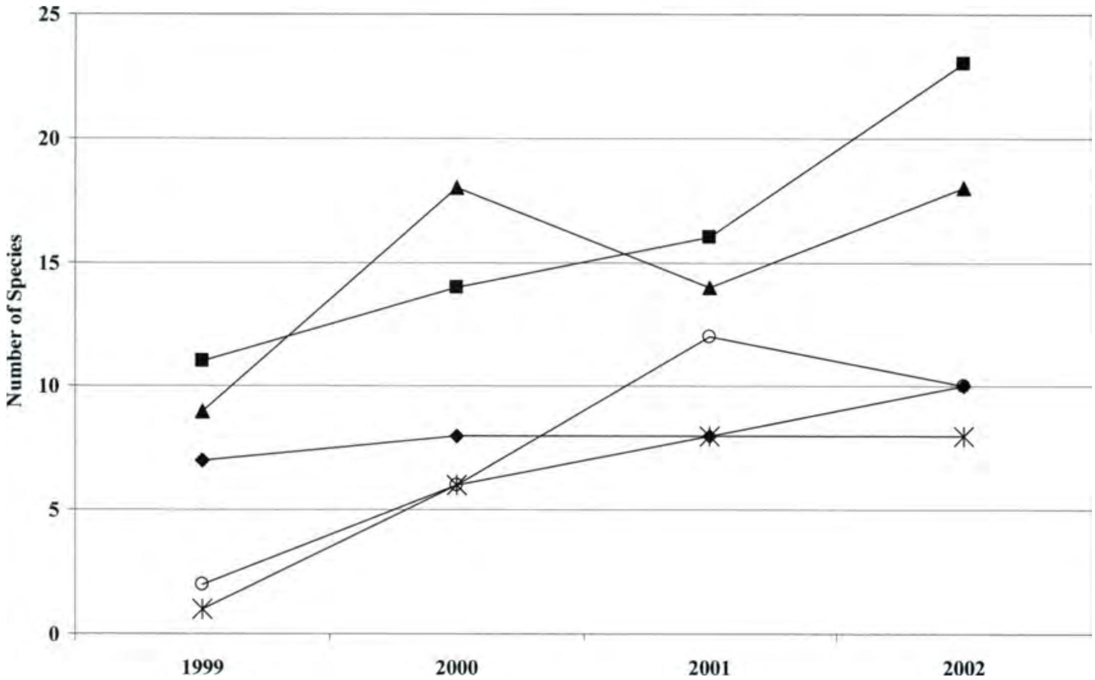

Fig. 2. Avian response to shrub thinning at each site: number of species.

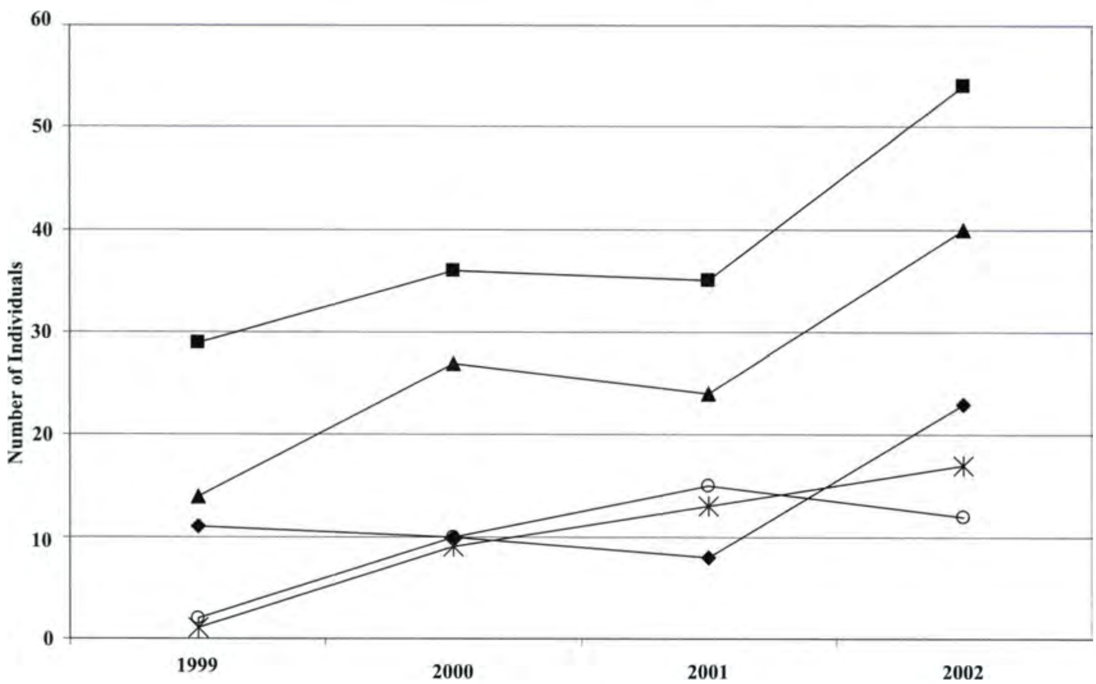

Fig. 3. Avian response to shrub thinning at each site: number of individual birds.

Table 4. Average avian response to shrub thinning on ROW of Orange and Rockland Utilities

Year	Percent increase in species	Percent increase in individuals
1999–2000	73%	61%
2000–2001	12%	3%
2001–2002	19%	54%
1999–2002	130%	156%

The values are mean increase from one year to the next for five of six experimental sites. Results from one site are omitted because of beaver flooding.

increase in the initial year. After three years, the numbers of individuals increased almost 2-fold or more at each site (Fig. 3), suggesting the response was not due to some site-specific factor. The sum of the number of individuals for all sites increased by 156% during this study (Table 4).

DISCUSSION AND CONCLUSIONS

Results from several years obtained from many areas throughout northeastern United States show that nesting success on ROW is usually sufficient to sustain bird populations. Surveys throughout northeastern US in landscapes that were largely forested found that nesting success in forests adjacent to ROW were sufficient to sustain bird populations. Low nesting success in 2002 contrasts with results from earlier and later years. Low success in 2002 occurred in a multi-state area and was not restricted to ROW. The low nesting success of 2002 almost certainly was due to an exceptional abundance of chipmunks.

The reduction of shrub density on ROW resulted in a major increase in the diversity and density of the avian community in southern New York. Some species, such as eastern towhee and gray catbird (*Dumatella carolinensis*) prefer dense shrub cover (Confer and Pascoe, 2003) and might be reduced following widespread thinning of shrub. This did not occur at our sites, perhaps because shrubs along the ROW edge provided sufficient shrubby habitat. A long segment of ROW will support the greatest avian diversity by maintaining some sections with greater shrub cover and other sections with greater herb cover. Because greater herb cover supports greater density and diversity of birds than any other single habitat type and because this habitat supports some of the particularly rare and rapidly declining species such as golden-winged and blue-winged warblers, management should favor greater herb cover in most areas.

REFERENCES

Confer, John L. 2002. Management, vegetative structure and shrub land birds on rights-of-way. In Environmental Concerns in Rights-of-Way Management, Seventh International Symposium (J.W. Goodrich-Mahoney, Ed.). Electric Power Research Institute, Washington, D.C.

Confer, J.L. and S. Pascoe. 2003. Avian communities on utility rights-of-ways and other managed shrub lands in the northeastern United States. Forest Ecology and Management 185: 193–205.

Holmes, R.T., T.W. Sherry, P.P. Marra, and K.E. Petit. 1992. Multiple-brooding and productivity of a Neotropical migrant, the Black-throated Blue Warbler (Dendroica caerulescens), in an unfragmented temperate forest. Auk 109: 321–333.

Holmes, R.T., P.P. Marra, and T.W. Sherry. 1996. Habitat-specific demography of breeding Black-throated Blue Warblers (*Dendroica caerulescens*): Implications for population dynamics. Journal of Animal Ecology 65: 183–195.

Nice, M.M. 1957. Nesting success in altricial birds. Auk 74, 305–321.

Ostfeld, R.S. and F. Keesing. 2000. Pulsed resources and community dynamics of consumers in terrestrial ecosystems. Trends in Ecology and Evolution 15: 232–236.

Sauer, J.R., J.E. Hines, and J. Fallon. 2004. The North American Breeding Bird Survey, Results and Analysis 1966–2003. Version 2004.1. USGS Patuxent Wildlife Research Center, Laurel, MD.

Sherry, T.W. and R.T. Holmes. 1992. Population fluctuations in a long-distance Neotropical migrant: Demographic evidence for the importance of breeding season events in the American Redstart. Pages 431–442. in Ecology and Conservation of Neotropical Migrant Landbirds (J.M. Hagen III and D.W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

BIOGRAPHICAL SKETCH

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Dr. Confer teaches at Ithaca College. For nearly 30 years his research has focused on shrub land birds. During this time, shrub land habitat has declined in northeastern United States as forest regeneration progressed. This has led to a concurrent decline in shrub land birds and an increase in woodland birds. Because utilities manage far more shrub land area than the sum of all other habitat managers in eastern United States, Confer has been pleased to work with the Electric Power Research Institute, New England Electric Systems, National Grid USA, Central Maine Power, New York State Electric and Gas, and Orange and Rockland Utilities to assess management options that enhance avian communities. Results described in this study provide additional documentation of high nesting success on ROW and new evidence that low to moderate densities of shrub support the greatest density and diversity for the avian community.

Bird-Caused Outages Along the Bernalillo to Blackwater 345 kV Line in New Mexico

John Acklen and Douglas Campbell

The Bernalillo to Blackwater 345 kV line experiences more faults than any other line in the Public Service Company of New Mexico system. The lattice steel configuration provides a ready home to nesting birds and it has commonly been assumed that nests, predominately made of bailing wire, were the cause of non-equipment related faults. As a consequence, over the years the company has systematically removed the nests at considerable expense. This paper evaluates possible causes of line faults—that faults result from nests, that faults result from bird streamers, and that faults result from rain and wind. Nesting, weather, and line fault data were analyzed using a Geographical Information System. The results suggest that streamers, not bird nests, are a likely cause for most faults. Wind and precipitation probably play a role but no pattern is clear. Significant correlations have been found between frequencies of migrating birds in the fall and line faults. Experimental bird guards and diverters were installed in the autumn of 2004 beginning in areas of frequent faulting. Continuing evaluation and retrofitting are suggested as the most prudent course of action to increase system reliability.

Keywords: Line faults, streamers, flashovers, air gap, conductors, buteos, right-of-way

INTRODUCTION

Since it was constructed in 1985, Public Service Company of New Mexico (PNM)'s Bernalillo to Black Water (BB) 345 kV line has experienced more line faults than any other transmission line in PNM's system. Approximately 216 miles in length, the BB line runs from tree-covered upland valleys just north of Albuquerque to the grass-covered plains of eastern New Mexico near Clovis. Important landforms along the line include the Pecos River located near the midpoint of the line and Taiban Mesa, which constitutes the most pronounced topographic relief evident on the eastern plains. Although the BB line accounts for only 30% of PNM's total system length, it contributes approximately 70% of the faults. It is also the line with the most bird nests. The lattice steel guyed delta and four post angle configurations provide ready homes for nesting raptors and ravens. Data suggest that, on average, birds construct over 800 nests every two years. It has commonly been assumed that nests result in faults, and nest removals have been undertaken four times in the last eight years. This fix is temporary and expensive. It was during the last nest removal project conducted in early spring of 2002 that PNM began to question its working assumption. Input from Chris van Rooyen and Rick Harness coupled with a critical review of relevant literature suggested that bird streamers might be responsible for faults observed on transmission lines in South Africa and South Florida and perhaps New Mexico as well. Unlike some areas, such as South Africa where bird interactions cause frequent faults, patterns in New Mexico are subtle with much lower fault frequencies.

This analysis was constructed to critically evaluate three hypotheses: that faults are related to nests as has been commonly assumed in the past; that faults are related to bird streamers; or that faults are related to weather patterns, not birds. Data sources include fault type, location, time of day and nest location by structure and position on structure. Nest location data were collected by helicopter in 1999 and 2002 in conjunction

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with biological field studies. The present analysis focuses on 41 single-phase faults through 2002 for which reliable location data were available.

ASSESSING THE ROLE OF NESTS AS THE CAUSE OF LINE FAULTS

Nests themselves probably do not cause faults but when nesting materials, including sticks and wire, are introduced into the intervening space between the steel structure and the energized conductor, faults can result. The following discussions frame expectations, should nests be responsible for faults occurring on the BB line.

If nest materials do cause faults, the following expectations should be met:

- There should be a strong correlation between faults and nest locations.
- Faults should occur most frequently during the spring nest-building season when nest material is brought into the vicinity of the conductors.
- Faulting should occur more frequently on phases below the cross-arms where nests occur most frequently.
- Because nest building is a daytime activity, faults should occur during the daylight hours.
- Nest removal should result in a measurable reduction in faults in the year following removal.

None of these expectations were met. Nest cluster zones were developed to measure the intensity and location of nesting activity along the line. Each transmission line structure was analyzed for the frequency of nests on structures located on either side of it. A nest cluster was defined as the presence of ten nests within five structures either forward or backward from a given structure (Fig. 1). Whereas the 1999 nest clusters include 53% of the entire length of the line, 59% of all the single-phase line faults occur within those clusters. In 2002, whereas 28% of the line length occurred within nest clusters, 36% of the faults fell within them. Over 50% of line faults fell outside of nest clusters. Although the sample size of 1999 and 2002 faults was too small for statistical evaluation, the data appear to indicate that there is only a slightly greater probability of

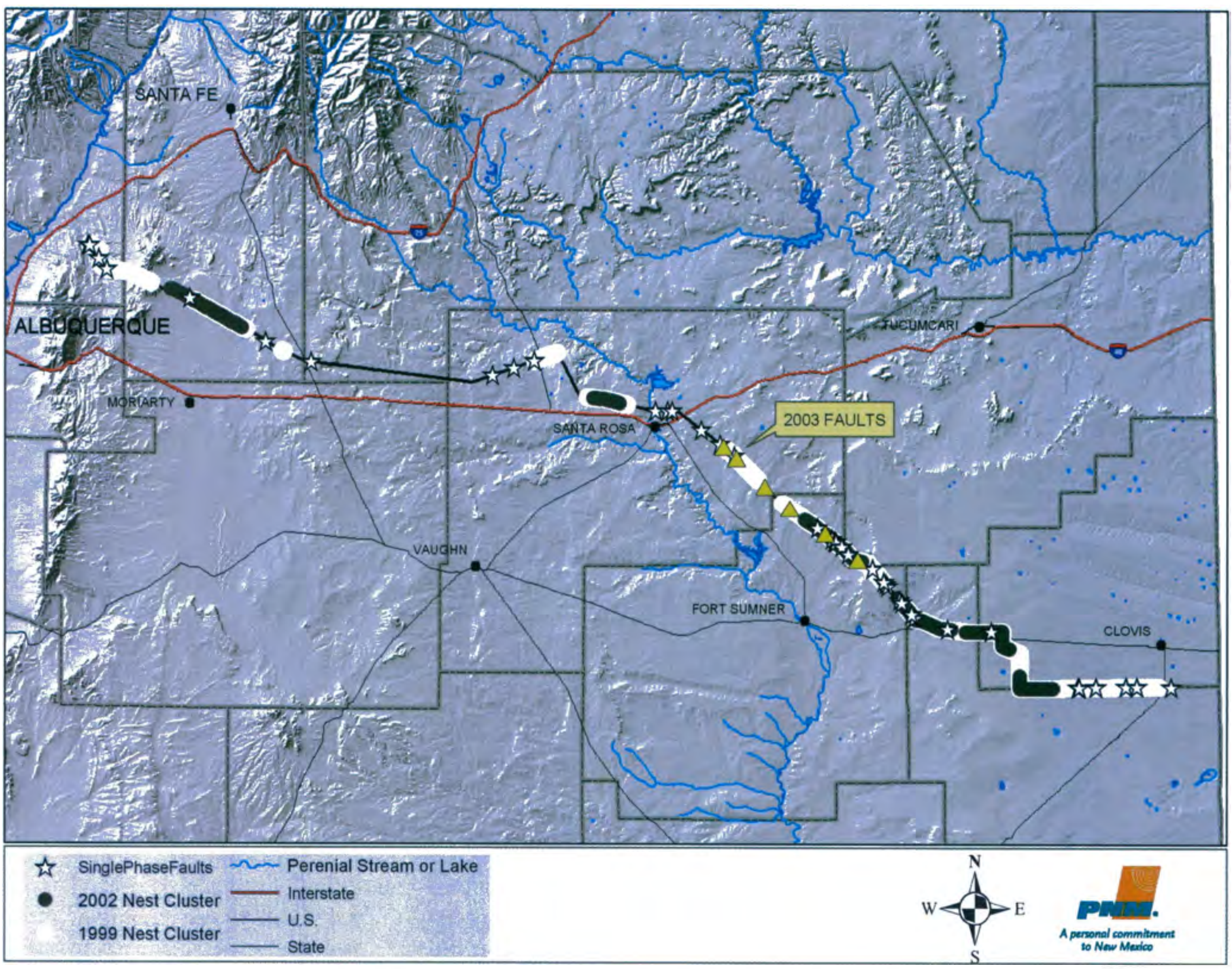

Fig. 1. Line-related faults in relation to 1999 and 2002 nest clusters.

a given fault occurring within a nest cluster than random chance would dictate.

If faults are related to nests, then most faults should occur during the nest-building season in the spring when birds bring sticks and wire up past the conductors on the way to the nest location. If wind dislodging nest materials is an important variable, faults should also occur most frequently during the spring. If either of these expectations is correct, there should be a statistically greater number of line faults during the spring. This expectation is not supported. Faults occur far more frequently in September than any other month. Examination of faults by season indicates that faults throughout the summer (26.7%), fall (33.3%), and winter (24.4%) are evenly distributed with slightly fewer faults in the spring (15.6%). Seasonality data indicate that less than 16% of the observed faults occur when birds are building nests. There is no statistical evidence to support the expectation that faults occur more frequently during nest building season or during spring when conditions are the most windy ($\chi 2 = 1.3$, $p < 0.732$).

If nests are related to faults, they should occur most frequently on the phases closest to the most nests. Nest locations on the BB line structures are highly patterned, and the pattern observed in 2002 is considered typical. During 2002, nests were most frequently positioned at the extreme ends of the cross-arms (54.5%) higher than and to the side of the lower two conductors. Less frequently, nests were positioned at the top corners of the structures higher than but to the side of the uppermost conductor (32.6%). In contrast, 51% of the line faults occur on the upper center phase. These results indicate that faults were less common on phases closest to the most nests. Chi square statistics run on nest location show a significant difference in distribution of nests ($\chi 2 = 26.7$, $p < 0.001$). Examination of adjusted chi-square residuals show that birds prefer to construct nests in the north end of the crossarm and avoid the top nest locations although the frequency of faults on the northern phase is less than the upper center phase. This may reflect a behavioral preference for nest locations in which the structure provides shade from summer sun.

If nest construction activities do cause faults, then faults should occur more frequently during daylight hours when birds are building nests. Examination of

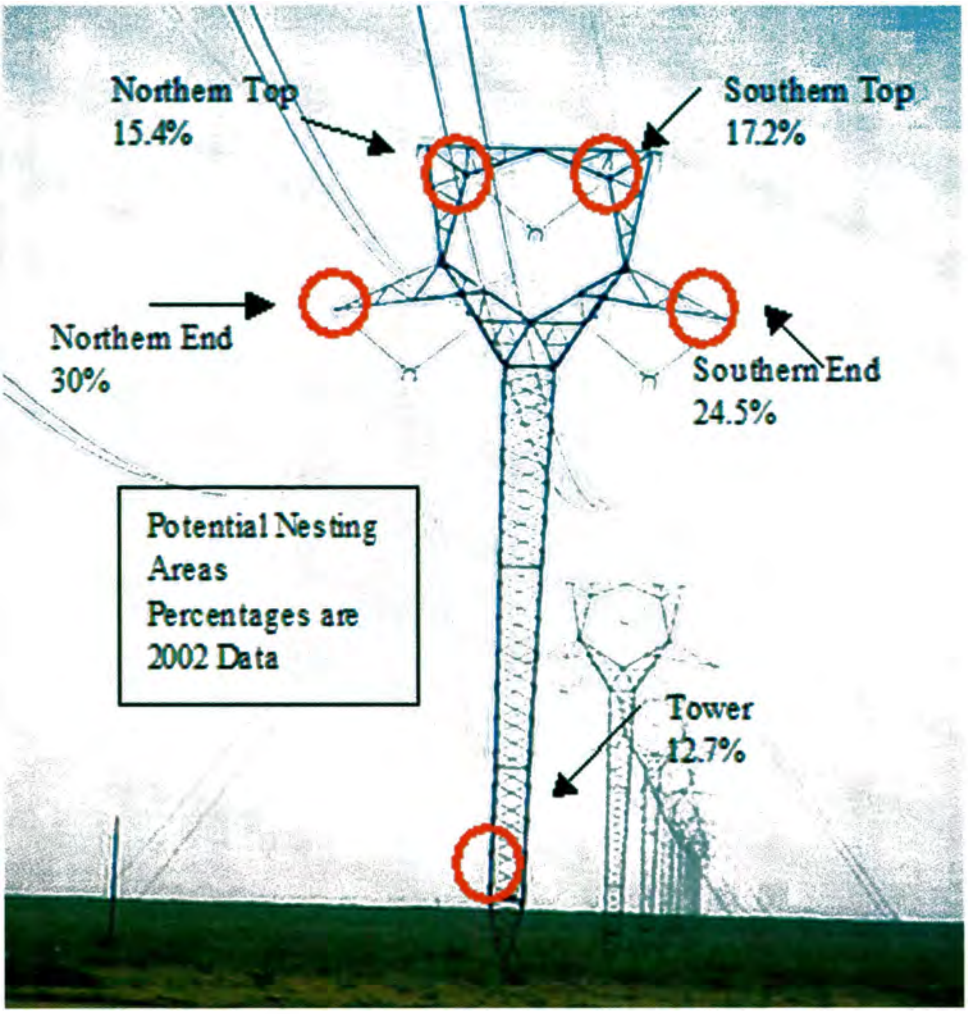

Fig. 2. 2002 nest location frequencies.

the figure indicates that faults occur more frequently in the pre-dawn hours, and to a lesser degree in the late evening. Thirty-six faults occurred during darkness, while only five of the 41 faults have occurred during daylight hours. This is a statistically different pattern ($\chi 2 = 12.9$, $p < 0.005$). Examination of the adjusted residuals indicates significantly more faults during the night and significantly fewer in the afternoon. Morning and evening faults are not significantly different from the null hypotheses.

Finally, if nest materials do cause faults, faults should decrease significantly in the year after nests are removed. Faults were significantly reduced from seven to two after nest removal in 1997. Closer examination of the 1998 faults indicates that five of seven occurred during the autumn months and consequently, were not related to nest construction. No decrease in the number of line faults was observed in years after removals. While other factors are certainly at work, nest removal does not appear to decrease the probability of line faults.

ASSESSING THE ROLE OF STREAMERS AS THE CAUSE OF LINE FAULTS

Studies conducted by Burnham (1994), van Rooyen and Taylor (1999), and Vosloo and van Rooyen (2001) have demonstrated the importance of bird streamers in transmission faults. Large birds can cause flashover events when long conductive excrement streamers short out the air gap between the energized conductor and the structure. Expectations for streamer-related faults are as follows:

- Due to the rapid digestion of birds, increased streamer releases are expected late at night and early in the morning as birds metabolize their last meal (Burnham, 1994; van Rooyen and Taylor, 1999). If streamers are a common cause of faults, a robust, bimodal distribution of faults with peaks late at night and early in the morning is expected.
- Whereas the cross-arms comprise the most favorable nesting location, the top of the structure above the center phase, is the highest and most favorable roosting location because it permits the best, unobstructed view of the surrounding countryside. For this reason, streamer-related faults should occur more commonly on the upper, center phase.
- If streamers do cause faults, a positive correlation between fault time of year and seasonally available resources would be expected.
- A positive correlation might be anticipated between habitat types supporting a favorable prey base and streamer-related faults.

Examination of the BB fault frequency graphed against the time of day does reveal a distinctive bimodal pattern with the highest number of faults occurring between 3 and 5 a.m. and a secondary peak between 9 and 12 p.m. (Fig. 3). Only five faults occur during daylight hours. As we have seen, this is a statistically significant pattern ($\chi 2 = 12.9$, $p < 0.005$). The observed pattern strongly supports the role of streamers in transmission line faults.

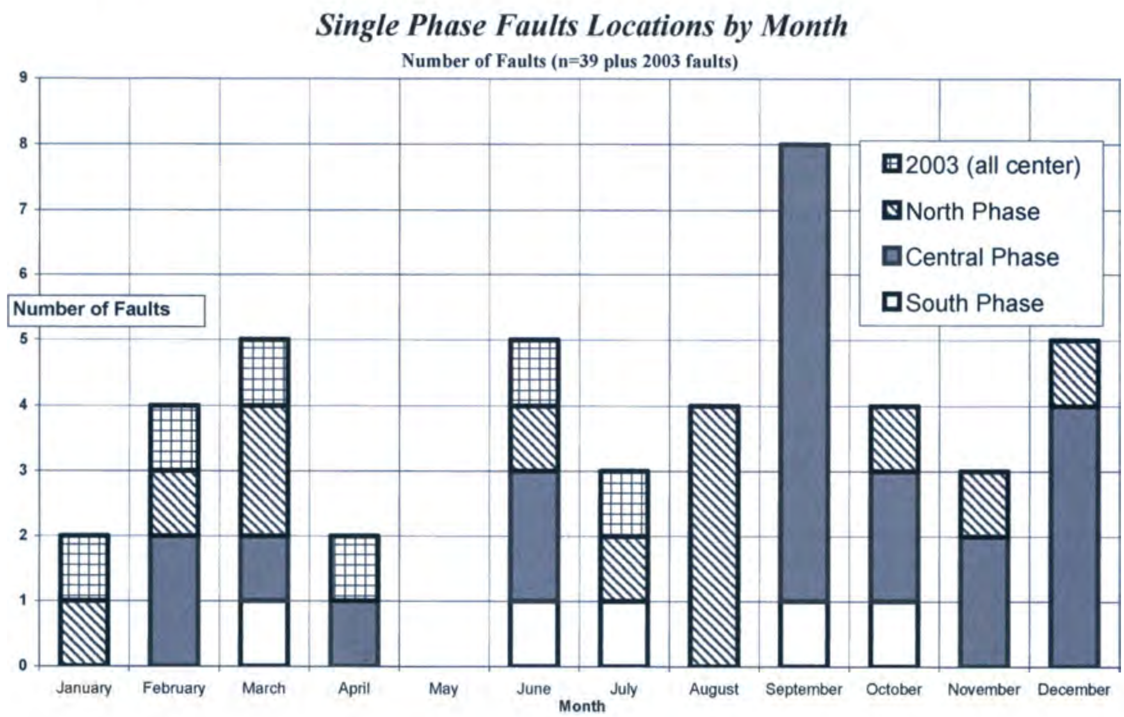

Fig. 3. Single phase faults by time of day.

Birds commonly use power line structures as roosts from which to hunt. Because it provides the best view, it is expected that the top of the structure would be used most frequently for roosting, even though nests more frequently occur in the cross-arms. If streamers do cause line faults, faults should occur most frequently on the highest conductor phase. This does seem to be the case. Faults do indeed occur more frequently on the highest center phase (51.3%) in spite of the fact that nests are far more common in the arms. The pattern is not, however, statistically significant ($\chi 2 = 5.1, p < 0.079$).

Faults by month are depicted to evaluate the correlation between fault time of year and the seasonality of prey base resources (Fig. 4). Faults occur most frequently in September, the same month in which crops are ripening. The graphic reveals some patterning in the time of year in which faults are experienced. The relatively fewer spring faults occur along the entire length of the line. The fault clusters around Santa Rosa near the center of the line are heavily weighted to the summer months and fall outside of identified nest clusters. Whereas some winter faults occur near the eastern end of the line, autumn faults are concentrated along Taiban Mesa and along the eastern end of the line.

The data examined above indicate a tendency for faults to occur more frequently during the fall months. Not insignificantly, Taiban Mesa is a known pathway for migrating raptors. Whereas the prominence of the Sandia Mountains located at the west end of the line as a migratory path during the spring is well documented (Smith, 2003; 2004); only recently has Taiban Mesa been recognized as a part of the Pecos River migration flyway. Given the autumn bias in the fault data, it would be interesting to know if Taiban Mesa is a more important flyway during autumn migration than in spring.

During spring and fall migration, the number of large birds in the area likely increases, albeit temporarily, creating additional risk of bird-line interactions. Both the number of faults and the frequency of migrating raptors passing through the area vary on an annual basis (Acklen et al., 2003; Smith, 2003; 2004). Therefore, if migratory raptors contribute to these line faults, then the annual rate of faulting during the migration seasons should be positively correlated with the rate of raptors migrating through the area.

Although there are no data specifically collected to quantify the migration through the BB line area, there are two long-term hawk migration watch sites in the vicinity of the BB line that may provide a useful index of the migration volume in the area during both spring and fall. The annual hawk migration passage rates published by HawkWatch International, Inc. was compared with the number of line faults during spring and fall to determine if there were any association between the number of faults and the number of hawks passing through the area (DeLong 2004). The total number of buteos and eagles observed each year

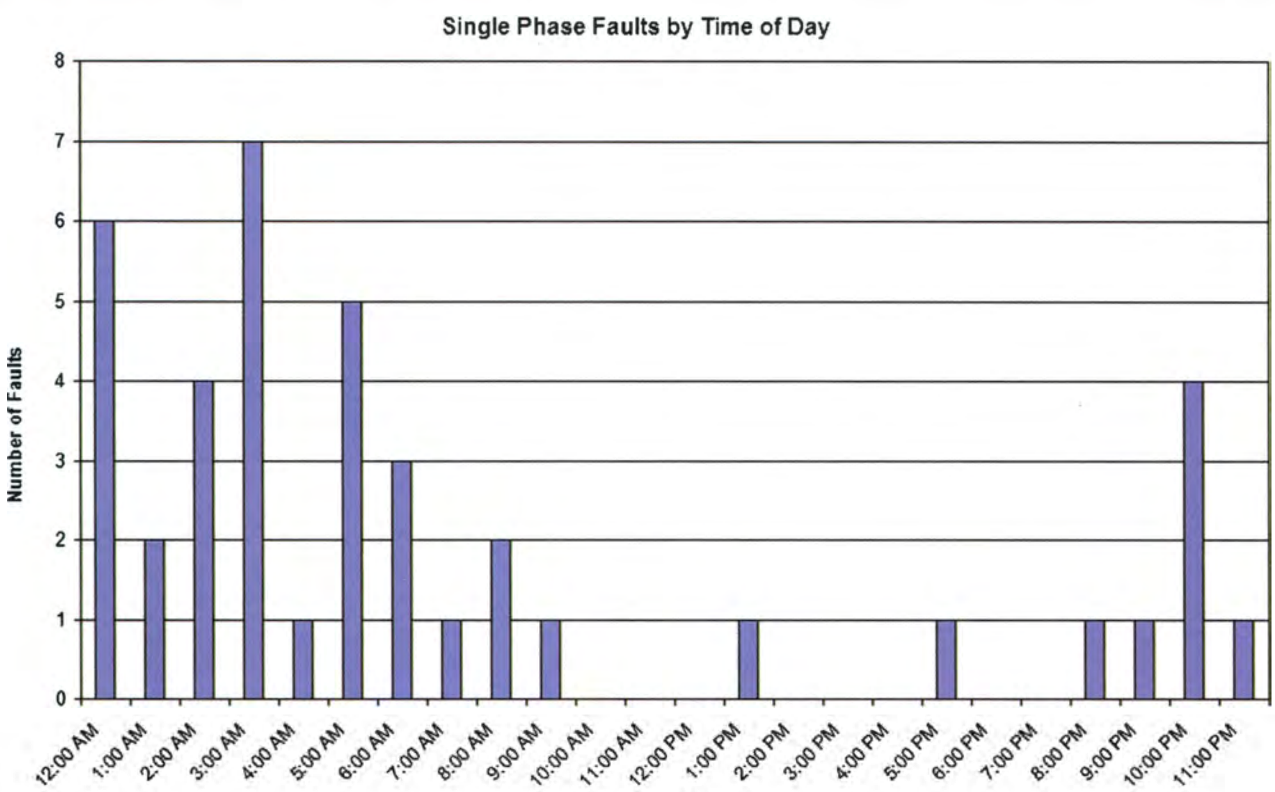

Fig. 4. Single phase fault locations by month.

since 1990 was used for the count dataset. Because of their large size, buteos and eagles are the raptors most likely to produce streamers of sufficient length to cause flashovers. Prominent species included in these counts are Red-tailed Hawk, Swainson's Hawk, and Golden Eagle. Ferruginous Hawks, Broad-winged Hawks, and Bald Eagles also are included. These species migrate through the plains as well as mountain areas and therefore are the most likely to represent the migrants that may interact with the BB line. Each year's total sum of eagles and buteos was divided by the number of observation hours, giving the number of buteos and eagles observed per hour for an entire migration season. The frequency of birds was compared with BB line faults of unknown cause from 1990 through 2003.

- *Spring*: There was no correlation between the number of spring line faults and birds per hour ($r = -0.05$). Hence, during the spring, there appears to be no association between the rate of raptors passing through the area and the number of faults occurring along the BB line.
- *Fall*: In the fall, there was a positive correlation between the number of faults and birds per hour ($r = 0.55$). Years with greater fall buteo and eagle passage rates (birds per hour) generally had higher rates of faulting. The correlation would have been even stronger ($r = 0.70$) except for the nonconformity of the 1997 data. Although the 1997 data generally conformed to the positive association, 1997 had a higher than expected number of line faults than the other years.

More studies are needed to evaluate the relevance of this correlation. Questions as to the applicability of raptor observations to the study area and interpretation of the spring data persist. However, the study provides additional support for the inference that large birds are contributing to the faults on the BB line.

Prey availability conditions the distribution of raptors. Just like the large birds themselves, their prey depends upon good sources of food and water. Lakes, ponds, and streams comprise major water sources along the line. Irrigated farmland provides a ready source of grain for rodents and small birds. The proximity of food and water should result in a higher concentration of large birds. A slight tendency for faults to occur close to areas with favorable prey base characteristics is observable in the BB data. On average, structure fault locations occur five miles from water sources and 4.6 miles from farmland while all structures average 5.4 miles from each of these sources (Fig. 5).

Fault clusters located along the BB line are patterned in their distribution. The most concentrated fault cluster located in the vicinity of Taiban Mesa is characterized by frequent autumn faults. The west end

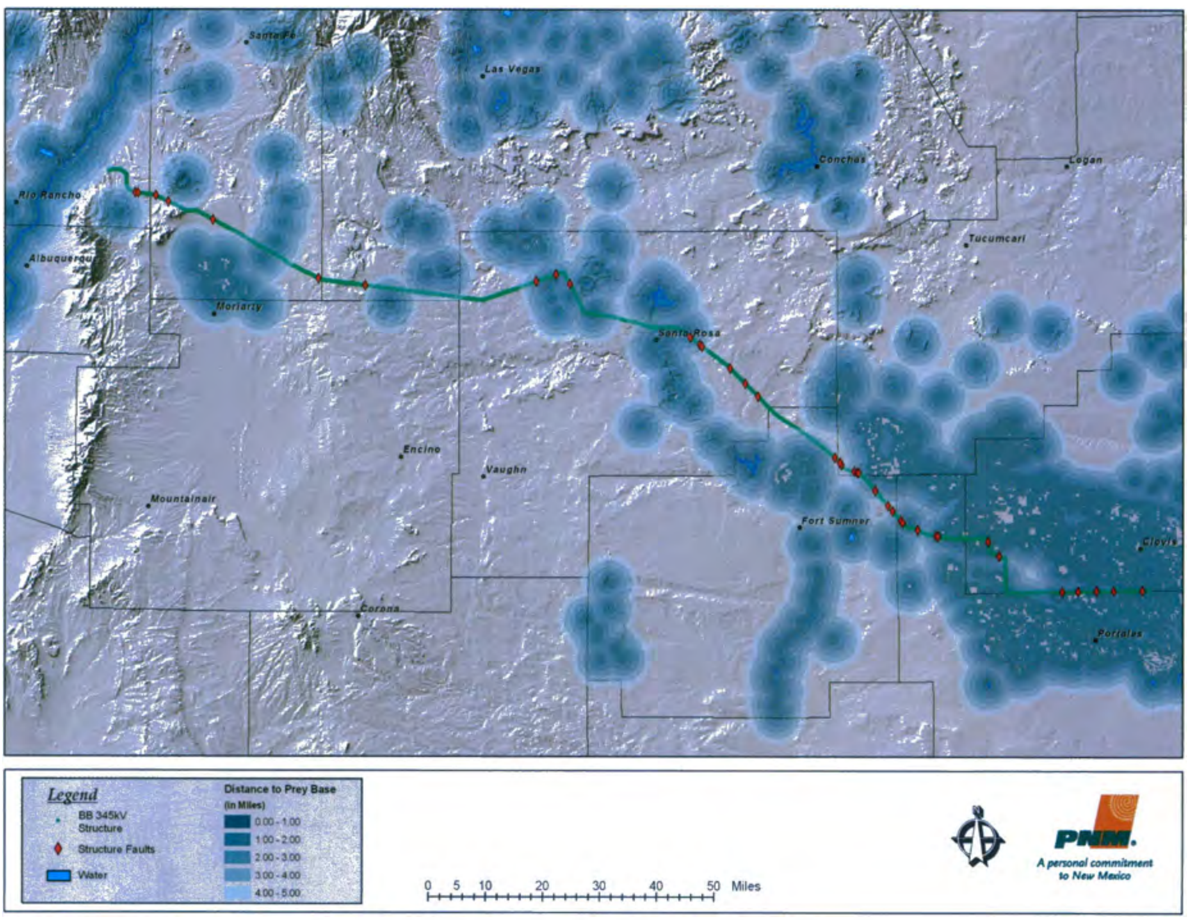

Fig. 5. Prey base (farmland and water) and single phase faults.

fault cluster located close to the east face of the Sandia Mountains at the extreme west end of the line consists of far fewer faults, mostly during the spring. A third diffuse fault cluster was documented on either side of the Pecos River near the center of the line and a more concentrated fault cluster was located at the extreme eastern end of the line. The observed use of power line structures by Ferruginous Hawks in the vicinity of prairie dogs prompted additional investigation of a possible correlation between line fault locations and prey base. Attempts to use aerial line inspection imagery to locate prairie dog towns documented only two colonies. Both, however, corresponded to fault clusters identified described above. The largest of the prairie dog towns is located on Taiban Mesa in the midst of the most concentrated fault cluster along the line. Another smaller prairie dog colony is located within the more diffuse west end fault cluster. At least in part, the location of prairie dog towns seems to condition the distribution of faults along the BB line, once again implicating large bird streamers in a causal role, especially during the autumn during migration. It should be noted that the field of view along the transmission line corridor in aerial imagery was limited to approximately 300 feet. Additional prairie dog town locations could be present outside of the BB corridor but well within the home range of large raptors using BB structures as perches.

ASSESSING THE ROLE OF WEATHER AS THE CAUSE OF LINE FAULTS

Weather seems like a reasonable explanation for single-phase faults. Unlike bird nests, weather obviously affects each transmission structure. Two weather factors were examined; wind speed and precipitation. Both high wind speeds and heavy rain can reasonably be expected to cause line faults.

If wind speed is a factor in faults, faults should occur more frequently on windy days. To test this, data from 27 faults with recorded daily average wind speeds was compared to average annual wind speed for the period 1992–2001 (NOAA, 1996). An ANOVA indicates that there is no significant difference between the average yearly wind speed, and the average wind speed on days with single-phase faults ($F = 2.44$, $p = 0.127$). Although the wind speed is on average higher for days with faults (9.07 mph versus 7.51 mph), this difference is not statistically significant. Average daily wind speed, therefore, does not appear to be a primary explanation for these faults.

If wind is not the cause for the faults, how about rainfall? If the faults occur on days with significant precipitation, then precipitation could be considered a causal agent to line faults. What is significant precipitation? For this analysis, at least 0.1 inches or rain in a 24-hour period is considered the cut-off for significance. For the line in general, an average of 27 out of 365 days meet this criteria, or 7.4 percent. For the 41 single-phase faults with precipitation data, only three out of 41 (7.3 percent) were on days with significant precipitation. Results of a chi-square analysis indicate that there are no significant differences the average precipitation and the rainfall recorded for days with faults ($\chi 2 = 0.0$, $p = 0.985$). In short, because most (82 percent) faults occurred on days that were dry, without measurable rainfall, precipitation is not a good explanation for single-phase line faults.

Based the above analysis, it is clear that weather is not a good explanation for single-phase faults on the BB line. Although the average wind speed was higher on days with faults versus the average day, this difference is not significant. Since most faults occur in the early morning hours, when New Mexico is traditionally less windy, this can be expected. Likewise, New Mexico is a dry state, where precipitation is relatively uncommon. Neither factor – wind nor rain – seems to explain the faults on the BB Line.

CONCLUSIONS

Study results demonstrated a correlation between line faults and expectations developed for faults from bird streamers. Expectations derived from the hypothesis that nests cause faults received little support, and whereas weather appears to play a role, it appears to be a minor one. There is some correspondence between nest locations and faults but at least half of the line faults fall outside of any nest clusters. If nest construction causes line faults, they should occur with significantly more frequency in the spring when nests are being built. If wind dislodging nest materials is an important variable, faults should also occur most frequently during the spring windy season. No such statistical correlations were evident. In fact, faults occur less frequently during the spring months than during other months of the year. If nests are related to faults, then faults should occur more frequently during the day when birds are actually building them. In fact, faults rarely occur during the day when birds would be building nests. If nests cause faults, faults should occur more frequently on lower phases closest to where nests occur in the greatest numbers. In fact, faults occur more frequently on the upper center phase whereas nests are more numerous lower down in the cross-arms. The analysis called into question the efficacy of nest removal and PNM has suspended this expensive exercise as a result.

There appears to be a strong correlation between bird streamers and faults. Faults occur far more frequently in the early morning hours at and just before dawn, late at night, and only extremely rarely during the day, a statistically significant pattern. Thus, line faults assume the classic bi-modal distribution first reported by Burnham (1994) and further elaborated upon by van Rooyen and Taylor (1999), and Vosloo and van Rooyen (2001). Faults tend to occur more frequently on the upper phase below favored bird roosting locations, although this pattern is not statistically significant. Comparisons with regional migration data revealed a statistically significant correlation between raptor and fault frequencies in the autumn but not in the spring. The west end cluster characterized by spring faults is located along a well-documented spring migration flyway. The cluster near Taiban Mesa is the most concentrated with a strong autumn bias in the faults that occur there. Taiban Mesa has been recently documented as a migration flyway. Faults occur more frequently in habitats that support more prey as defined by available water sources and agricultural fields. The densest fault cluster documented along the BB line occurs within a prairie dog town.

The relatively low number of faults experienced on the BB line may not justify the expense of total retrofits to eliminate streamers as the cause of single-phase line faults. Nonetheless, the persistent, albeit infrequent faults are vexing enough to PNM to prompt experiments designed to evaluate mitigation alternatives. High-density polyethelene (HDPE) welded-rod bird diverters have all but eliminated streamers as a significant cause of transmission faults on a significant portion of the Eskom system in South Africa (van Rooyen and Taylor, 1999; Vosloo and van Rooyen 2001). Experimental retrofits were installed during a two-week outage on the BB line in autumn of 2004. Ten structures were retrofitted with HDPE welded-rod devices (Mission bird diverters) and 13 structures with the "Firefly" bird flapper/diverter in the largest fault cluster located on and around Taiban Mesa. The "Firefly" is a hazing device that may discourage perching and or nesting. A program of systematic observation was initiated and is currently in process. The efficacy of each will be compared and contrasted as a part of the experiment.

REFERENCES

Acklen, J.C., Z. Bates, and D. Campbell. 2003. The BB Line: Evaluating the Roles of Birds in Line Faults, Public Service Company of New Mexico Environmental Services Department, Albuquerque.

Burnham, J.T. 1994. Streamer Flashovers on FPL Transmission Lines. Florida Power and Light, Juno Beach, Florida.

DeLong, J.P. 2004. Correlation of BB Line Faults and Spring and Fall Hawk Migration Count Data, 1990–2003. Eagle Environmental, Inc., Albuquerque, New Mexico.

NOAA. 1996. National Climatic Data Center at http://lwf.ncdc.noaa.gov/oh/cdnc.html.

Smith, J.P. 2003. Spring 2003 Raptor Migration Studies in the Sandia Mountains of Central New Mexico. HawkWatch International, Inc., Salt Lake City, Utah.

Smith, J.P. 2004. Fall 2003 Raptor Migration Studies in the Manzano Mountains of Central New Mexico. HawkWatch International, Inc., Salt Lake City, Utah.

van Rooyen, C. and P. Taylor. 1999. Streamers As Probable Cause of Raptor Electrocutions in South Africa. In Avian Interactions with Utility and Communication Structures, Proceedings of a Workshop held in Charleston, South Carolina, December 2–3, 1999, Electric Power Research Institute.

Vosloo, H. and C. van Rooyen. 2001. Eliminating Streamers as a Cause of Faulting on Transmission Lines. Paper presented to Edison Electric Institute.

BIOGRAPHICAL SKETCHES

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As a senior environmental scientist, Mr. Acklen works in planning and permitting major electric and gas construction projects throughout PNM's service area. Mr. Acklen is an archaeologist by training and has worked in southwest archaeology since the mid-1970s. Mr. Acklen received his Master of Arts degree in Anthropology with a specialty in Archaeology from the University of New Mexico in 1981. He is in charge of PNM's migratory bird protection program. In collaboration with the US Fish and Wildlife Service and conservation groups, Mr. Acklen is a founding member of the New Mexico Avian Protection Plan working group. He is also PNM's Avian Power Line Interaction Committee representative. John volunteers with raptor research and conservation organizations including Hawks Aloft and HawkWatch, International.

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Mr. Campbell serves as the Manager of Environmental Planning and Permitting at PNM. With over 23 years of experience in the industry, he has investigated a broad range of environmental issues and coordinates studies incorporating and expanding the use of GIS analysis. Mr. Campbell holds a BS degree in anthropology from the University of New Mexico.

Bird Mortality Near High Voltage Transmission Lines in Burlington and Hamilton, Ontario, Canada

G.C. Barrett and D.V. (Chip) Weseloh

Several high voltage transmission lines extend above portions of the Burlington and Hamilton beaches of western Lake Ontario, Canada. Hamilton Harbour and Lake Ontario lie on either side of the lines; both areas are heavily utilized by waterfowl and colonial waterbirds. Over 27,000 pairs of colonial waterbirds nested around Hamilton Harbour in 2003. Surveys were conducted throughout the year between 2000 and 2003 to monitor numbers and species of birds found dead or injured beneath the lines. Dead birds were marked or removed to prevent double counting. Surveys of Burlington beach, which began in 2000 revealed 43, 139, 71 and 50 dead birds from 2000 to 2003. Surveys at Hamilton beach began in 2002 from which 209 and 211 dead birds were recorded respectively. Twenty-two species of either dead or injured birds were found beneath the lines with double-crested cormorants and ring-billed gulls observed most frequently. During December 2001, Hydro One (the power authority) installed 145 bird flight diverters along two kilometres of the skywire (overhead ground wire) running above Burlington beach. More surveys will be necessary to determine if the observed decrease in bird mortality along Burlington beach is due to these diverters and whether these or some other type of bird deterrent should be installed on the wires above Hamilton beach.

Keywords: Avian collisions, mortality, transmission power lines, flight diverters, Ontario, Canada, right-of-way

INTRODUCTION

Birds face many anthropogenic threats including habitat loss, contaminants, feral domestic animals and collisions with structures. Annual human-caused bird mortality in North America has been estimated in the billions of bird deaths per year (Klem, 1990; Corcoran, 1999; Erickson et al., 2001; Manville, 2001a; 2001b). Bird kills as a result of collisions with electrical transmission lines range from hundreds of thousands to perhaps 175 million (Koops, 1987 cited in Manville, 2002; Erickson et al., 2001). This is not a recent phenomenon, as birds dying after colliding with telegraph and power lines were reported as early as 1876 (Coues, 1876; Emerson, 1904), however, it is a growing concern as the demand for electricity and the number of transmission lines around the world increases (APLIC, 1994; Manville, 2002). The cumulative toll of bird collisions with power lines has the potential to have serious conservation impacts for some threatened bird populations (Faanes, 1987; Lewis, 1993; Bevanger, 1994; 1998).

Factors which appear to influence the rate of bird collisions with transmission lines include habitat use patterns, land use and ownership, weather conditions, time of day, flocking behaviour, age and sex, body size, flight behaviour, and placement, orientation and configuration of transmission lines (APLIC, 1994; Henderson et al., 1996; Bevanger, 1998; Janss, 2000; Deng and Frederick, 2001; Crowder and Rhodes, 2002). A number of studies have shown that marking wires reduces the number of bird collisions with transmission lines (APLIC, 1994; Brown and Drewien, 1995; Savereno et al., 1996; Janss and Ferrer, 1998; Alonso and Alonso, 1999; De La Zerda and Rosselli, 2002).

Although avian collisions with transmission lines occur around the world (Hebert and Reese, 1995; Ferrer and Janss, 1999; Kerlinger, 2000; Erickson et al., 2001) documented information on the situation in Canada is limited (Weir, 1976). Our paper examines avian collision data collected at two transmission line

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locations in Ontario, one of which has had bird flight diverters attached. Our objective was to determine species diversity and numbers of birds being affected by these transmission lines.

STUDY AREA

Hamilton Harbour is located at the western end of Lake Ontario (43°16′24″N, 79°46′46″W) in Ontario, Canada (Fig. 1). It is separated from Lake Ontario by a sandbar and water exchange occurs through the human-made Burlington Ship Canal. Burlington and Hamilton beaches are located on the east side of the sandbar. Transmission lines, installed in 1970, run parallel to Burlington beach for its entire length (approximately two kilometres (km)), cross the Burlington Ship Canal and continue for approximately five km along Hamilton beach before turning inland. The transmission towers are spaced 220 metres (m) apart and are 50 m in height. They hold 12 conductor wires (six 115,000 volt and six 230,000 volt; diameter – 31 millimetres (mm)) and two skywires/overhead ground wires (diameter – 16 mm) (Michael Medeiros, Hydro One, pers. comm.). The skywires are approximately 14.6 m apart and the conducting wires are 21.6 m apart. Attached to the conducting wires are vibration dampers (317 mm wide, 76 mm high, 51 mm diameter) spaced approximately 30 m apart. Burlington and Hamilton beaches are predominantly sand and are utilized extensively by people during summer months. Located along the top of the dune area, which is 10–30 m back from the shoreline, is a multi-season, multi-use paved path that is also heavily used. Habitat beneath the transmission lines varies from open sand to manicured lawns, scrubby growth and sizeable trees, with some portions of the lines directly above Lake Ontario.

In December 2001, Hydro One installed 145 bird flight diverters (Energy Equipment; Auckland, New Zealand) along two km of the skywire running above Burlington beach. Using a helicopter, these swinging disc type diverters were clipped to the lake side skywire spaced 15 m apart; the harbour side skywire was not marked to avoid complications with its associated fibre optic cable (Michael Medeiros, Hydro One, pers. comm.). The bright orange discs are approximately 300 mm in diameter and are hinged allowing them to swing beneath the skywire in the wind, increasing their visibility.

Colonial waterbirds began breeding in Hamilton Harbour during the 1970s (Dobos et al., 1988). Since then, Hamilton Harbour has become one of the most important nesting areas on the Great Lakes for colonial waterbirds with six breeding species at a number of colony locations (Fig. 1) (Moore et al., 1995; Blokpoel and Tessier, 1996; Pekarik et al., 1997; Morris et al.,

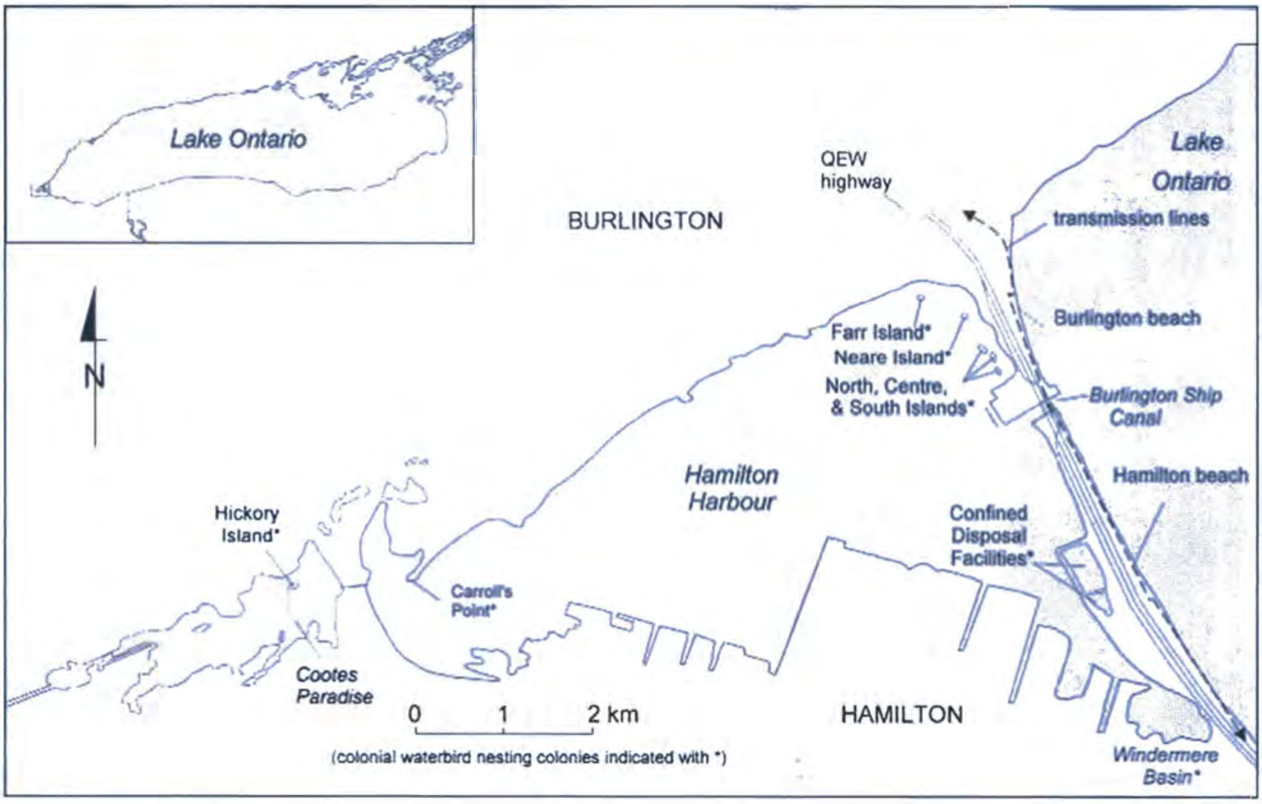

Fig. 1. Hamilton Harbour showing the locations of colonial waterbird nesting colonies and approximate location of high voltage transmission lines. Bird flight diverters were attached to the lake side skywire above Burlington beach. Inset map shows Hamilton Harbour in relation to Lake Ontario (shaded areas on both maps represents water).

2001). Additionally, Hamilton Harbour and the shallow western end of Lake Ontario are important areas for waterfowl with significant numbers present during seasonal migrations (Gebauer et al., 1992; 1993).

METHODS

Responding to increasing public concern regarding the collision of migratory birds with the transmission lines at this study area, surveys were initiated in 2000 to monitor the number and species of birds being injured and/or killed by the Burlington/Hamilton beach transmission lines. Beginning in May 2000, Canadian Wildlife Service (CWS) staff requested that the City of Burlington (who actively maintain their stretch of beach from late April to October) record the species and number of dead birds observed and to forward these data to CWS, to which they agreed. In 2002, we asked that they also record the location (span section) of any dead birds encountered. The City of Hamilton began their own beach maintenance program in 2003 and agreed to provide CWS with similar data for the period of time they maintained their beach (from May to September). It was assumed that all dead or injured birds found beneath the lines were a result of collision as no hunting is allowed in this area.

Both cities utilize beach grooming machines in addition to manual methods to maintain the "cleanliness" of their respective beaches on a daily basis (typically seven days a week during above mentioned months) with the focus being to remove accumulated algae, garbage and other non-desirable materials. City staff were provided information on how to identify the species of birds found and were encouraged to contact CWS when birds could not be identified, or if significant numbers of dead birds were observed. Hamilton beach maintenance staff were provided data sheets to record their observations. All dead birds encountered by city staff were removed.

Additional observations during 2000 to 2003 were provided by local birdwatchers and periodic surveys were conducted by the authors from 2001 to 2003 wherein dead birds were marked (spray paint on leg) or removed to prevent double counting. These additional censuses included non-beach areas beneath the transmission lines which would not have been routinely searched by city staff and some occurred during months when beach maintenance staff were not active. The authors' surveys also recorded data on the age (juvenile, adult, unknown) of dead or injured birds encountered.

Colonial waterbird nests were censused annually in Hamilton Harbour by CWS and local stakeholders. This was accomplished by visiting all colony locations and manually counting all apparently occupied nests (Pekarik et al., 1997). Nest censuses of the six waterbird species were timed to occur at different times during the spring, corresponding with the peak of the nesting period for each species (Blokpoel and Tessier, 1996).

RESULTS

Surveys of Burlington beach began in 2000 and continued through 2003 with the following numbers of dead birds observed: 2000 – 43, 2001 – 139, 2002 – 71, 2003 – 50 (Table 1). For the months common to all surveys between 2001 to 2003 (i.e., May to September) at Burlington beach, the numbers of dead birds observed each year were: 2001 – 111, 2002 – 68, 2003 – 45 (Table 1). Hamilton beach surveys began in 2002 with the following numbers of dead birds observed: 2002 – 209, 2003 – 211 (Table 1). Data provided by the City of Burlington, along with some of the observations provided by local birdwatchers, did not always include specific dates or span locations where birds were found. For 2001–2003, when these data were recorded monthly, totals indicated that the highest numbers of dead birds were found in August 2001 (50) for Burlington beach, and June 2003 (62) for Hamilton beach (Table 1).

Twenty-two species of birds were found dead or injured at our study area from 2000 to 2003 (Table 2). Double-crested cormorants (*Phalacrocorax auritus*) were

Table 1. Monthly totals of dead and injured birds found beneath the transmission lines during surveys of Burlington and Hamilton, Ontario beaches, 2000–2003

Month/Year	Burlington beach		Hamilton beach	
	Dead	Injured	Dead	Injured
2000 TOTAL	43	n/d	n/d	n/d
January to March/2001	18*	n/d	n/d	n/d
May/2001	27	n/d	n/d	n/d
June/2001	6	n/d	n/d	n/d
July/2001	2	n/d	n/d	n/d
August/2001	50	n/d	57*	0*
September/2001	26	n/d	n/d	n/d
October/2001	10	n/d	n/d	n/d
2001 TOTAL	139	n/d	57	n/d
April/2002	2	n/d	n/d	n/d
May/2002	10	n/d	11	1
June/2002	5	n/d	12	4
July/2002	23	n/d	46	6
August/2002	24	n/d	41	0
September/2002	6	n/d	41	0
October/2002	n/d	n/d	58	0
November/2002	1	n/d	n/d	n/d
2002 TOTAL	71	n/d	209	11
January/2003	5	n/d	n/d	n/d
February/2003	0	n/d	n/d	n/d
March/2003	0	n/d	17*	0*
April/2003	0	n/d	29	3
May/2003	27	n/d	14	5
June/2003	0	n/d	62	8
July/2003	10	n/d	51	16
August/2003	3	n/d	27	5
September/2003	5	n/d	11	0
2003 TOTAL	50	n/d	211	37

* = partial survey only.
n/d = no data.

Table 2. Bird species found dead or injured beneath the transmission lines during surveys of Burlington and Hamilton, Ontario, beaches, 2000–2003

Species	Scientific name
loon spp.	*Gavia spp.*
double-crested cormorant	*Phalacrocorax auritus*
black-crowned night-heron	*Nycticorax nycticorax*
turkey vulture	*Cathartes aura*
Canada goose	*Branta canadensis*
trumpeter swan	*Cygnus buccinator*
mute swan	*Cygnus olor*
swan spp.	*Cygnus spp.*
gadwall	*Anas strepera*
mallard	*Anas platyrhynchos*
green-winged teal	*Anas carolinensis*
scaup spp.	*Aythya spp.*
white-winged scoter	*Melanitta fusca*
surf scoter	*Melanitta perspicillata*
scoter spp.	*Melanitta spp.*
long-tailed duck	*Clangula hyemalis*
bufflehead	*Bucephala albeola*
ruddy duck	*Oxyura jamaicensis*
duck spp.	
ruddy turnstone	*Arenaria interpres*
ring-billed gull	*Larus delawarensis*
herring gull	*Larus argentatus*
great black-backed gull	*Larus marinus*
ivory gull	*Pagophila eburnea*
gull spp.	
Caspian tern	*Sterna caspia*
tern spp.	*Sterna spp.*

the most commonly observed species of dead bird beneath the wires on both Burlington and Hamilton beaches while gulls were the group of species most often found injured (Table 3). In 2002, all of the injured birds found on Hamilton beach were ring-billed gulls (*Larus delawarensis*).

For those surveys where the age of dead and injured birds was determined by CWS, juvenile birds were almost always found more often than adults (Table 4). While some of the surveys found similar numbers of dead or injured adult and juvenile ring-billed gulls, juvenile double-crested cormorants were always encountered more frequently than adult cormorants (Table 4).

Ring-billed gulls were the most abundant nesting colonial waterbird in Hamilton Harbour with an average of 23,850 nests found from 2000 to 2003 (Table 5) (Morris et al., 2001; CWS unpubl.). Double-crested cormorants were the next most abundant species with an average of 1,507 nests during the same time period. From 2000 to 2003, the populations of five of the six species of colonial waterbird nesting in Hamilton Harbour remained stable. Double-crested cormorants, however, increased approximately 61%, from 1,143 to 1,886 nests.

Table 3. Yearly totals with species/groups delineated for dead and injured birds found beneath the transmission lines during surveys of Burlington and Hamilton, Ontario beaches, 2000–2003

Year	Species/Group	Burlington beach		Hamilton beach	
		Dead	Injured	Dead	Injured
2000	double-crested cormorant	33	n/d	n/d	n/d
	gull spp.	10	n/d	n/d	n/d
	waterfowl spp.	0	n/d	n/d	n/d
	other spp.	0	n/d	n/d	n/d
	TOTAL	43	n/d	n/d	n/d
2001	double-crested cormorant	103	n/d	57	n/d
	gull spp.	21	n/d	0	n/d
	waterfowl spp.	14	n/d	0	n/d
	other spp.	1	n/d	0	n/d
	TOTAL	139	n/d	57*	n/d
2002	double-crested cormorant	56	n/d	164	0
	gull spp.	10	n/d	35	11
	waterfowl spp.	3	n/d	6	0
	other spp.	2	n/d	4	0
	TOTAL	71	n/d	209	11
2003	double-crested cormorant	18	n/d	54	1
	gull spp.	0	n/d	69	30
	waterfowl spp.	32**	n/d	82***	5
	other spp.	0	n/d	6	1
	TOTAL	50	n/d	211	37
2000–03 TOTALS	double-crested cormorant	210	n/d	275	1
	gull spp.	41	n/d	104	41
	waterfowl spp.	49	n/d	88	5
	other spp.	3	n/d	10	1
	TOTAL	303	n/d	477	48

* = partial survey (only three spans to south of Burlington Ship Canal searched).
** = 15 (46.9%) of these individuals were identified as "duck spp."
*** = 46 (56.9%) of these individuals were identified as "duck spp."
n/d = no data.

Table 4. Age composition of dead and injured double-crested cormorants and ring-billed gulls found on individual surveys beneath the transmission lines of Burlington and Hamilton, Ontario beaches, 2001–2003

Date	Location	Species	Age			
			Adult	Juvenile	Unknown	Total
17 August 2001	Burlington beach	double-crested cormorant	2 (12.5%)	7 (43.7%)	7** (43.7%)	16
23 August 2001	Hamilton beach*	double-crested cormorant	4 (7.0%)	33 (57.9%)	20** (35.1%)	57
7 July 2002	Hamilton beach	double-crested cormorant	8 (33.3%)	16 (66.7%)	0	24
21 August 2002	Hamilton beach	double-crested cormorant	4 (18.2%)	18 (81.8%)	0	22
5 September 2002	Hamilton beach	double-crested cormorant	1 (4.2%)	23 (95.8%)	0	24
4 October 2002	Hamilton beach	double-crested cormorant	1 (3.2%)	29 (93.5%)	1 (3.2%)	31
9 September 2003	Hamilton beach	double-crested cormorant	0	7 (100%)	0	7
7 July 2002	Hamilton beach	ring-billed gull	4 (50.0%)	4 (50.0%)	0	8
21 August 2002	Hamilton beach	ring-billed gull	0	4 (100%)	0	4
29 April 2003	Hamilton beach	ring-billed gull	11 (100%)	0	0	11
14 July 2003	Hamilton beach	ring-billed gull	6 (66.7%)	3 (33.3%)	0	9

* = partial survey (only three spans to south of Burlington Ship Canal searched).
** = too far decomposed to determine age.

Table 5. Number of colonial waterbird nests in Hamilton Harbour, Ontario, 2000–2003

	2000	2001	2002	2003
double-crested cormorant	1143	1268	1730	1886
black-crowned night-heron	133	115	103	134
ring-billed gull	23884	23808	23357	24352
herring gull	271	251	245	251
Caspian tern	415	413	426	361
common tern	562	639	668	655
Total	**26408**	**26494**	**26529**	**27639**

DISCUSSION

Previous studies have shown that a critical factor influencing the collision of birds with transmission lines is the frequency with which birds must cross lines within their daily use area – collision rates increase where lines separate feeding from nesting or roosting areas (McNeil et al., 1985; APLIC, 1994). The large numbers of nesting waterbirds (Table 5) (Moore et al., 1995; Blokpoel and Tessier, 1996; Pekarik et al., 1997; Morris et al., 2001) and seasonally abundant waterfowl (Gebauer et al., 1992; Gebauer et al., 1993) in Hamilton Harbour are separated from Lake Ontario by a narrow sandbar over which transmission lines must be navigated during the frequent foraging bouts between these two bodies of water. Our data suggest that some of these bird species are colliding with the transmission lines at this location.

While our current study has not determined whether birds are hitting the skywires/overhead ground wires or the conducting wires at this location, the assumption was that the skywires were responsible for the majority of these collisions. When compared with the conducting wires, the skywires at our study area are of a smaller diameter, and prior to the installation of bird flight diverters, did not have any objects attached to make them more visible. Faanes (1987) and Savereno et al. (1996), respectively, report 93.6% and 82% of the bird strikes observed occurred with skywires. Supporting these findings, APLIC (1994) states that overhead ground wires were the major cause of bird collisions with power lines.

The effectiveness of different types of wire marker devices and different installation techniques are well documented in APLIC (1994). Markers have been shown to reduce the mortality at transmission lines by 50–80% (Brown and Drewein, 1995; Savereno et al., 1996; Janss and Ferrer, 1998; Alonso and Alonso, 1999). More recent studies by De La Zerda and Rosselli (2002), report that yellow polypropylene spiral diverters (250 mm diameter, 800 mm length) reduced both the collision rate and affected bird flight behaviour in the vicinity of the lines. Several studies report on the effectiveness of spiral diverters when they were spaced 10 m apart in an alternating style on both skywires so that to a bird they appeared on approach to be 5 m apart (Janss and Ferrer, 1998; De La Zerda and Rosselli, 2002). At our study location, Hydro One was unable to alternate the bird flight diverters due to the presence of a fibre optic cable on the harbour side skywire.

A confounding factor regarding bird collisions at our study areas is the presence of the Skyway Bridge (10 lanes wide, 2.6 km long, maximum height of 43 m where the bridge crosses over the Burlington Ship Canal). This concrete and steel bridge provides a strong visible barrier for birds to fly over, however, the transmission lines are parallel to and immediately to the east of the bridge. This means that birds flying west to east (from Hamilton Harbour to Lake Ontario) do not have much time/space to correct their flight trajectory before they are in amongst the transmission wires. APLIC (1994) suggested that birds can be distracted by flying over a solid structure such as a bridge, only to collide with a less obvious nearby transmission line. In a similar manner, height of vegetation adjacent to transmission lines can also influence bird collisions.

Studies examining the effects of vegetation and bird collisions with wires have shown that lines placed at or beneath the height of nearby trees rarely present a problem as birds will gain altitude to clear the highly visible tree line, and hence avoid striking the adjacent powerline (Thompson, 1978; Raevel and Tombal, 1991 cited in APLIC, 1994).

Double-crested cormorants were the most commonly observed species found dead beneath the wires on both Burlington and Hamilton beaches (Table 3), although they are not the most abundant colonial nesting waterbird in Hamilton Harbour (Table 5). Over-representation of cormorants among wire fatalities may be explained in part by their flying behaviour compared to other water birds. Double-crested cormorants have short wings with low aspect ratio, which results in low load-lifting ability (Hatch and Weseloh, 1999). Studies by Bevanger (1998), Janss (2000) and Crowder and Rhodes (2002) indicated that wing morphology and body weight (high wing loading and low wing aspect ratio) are key factors in determining which taxonomic families of birds are more prone to collision with wires. Flocking behaviour has also been suggested as a factor in bird collision rates (APLIC, 1994) and the double-crested cormorant is known to be a gregarious species that frequently flies in flocks (Hatch and Weseloh, 1999) which may put it at a higher risk of collision. Interestingly, the number of dead cormorants found along Burlington beach showed a declining trend during the period of this study (Table 3), even as their population in Hamilton Harbour increased (Table 5).

Species-at-risk have also been affected by the wires at our study area. trumpeter swans (*Cygnus buccinator*), a species for which an active reintroduction program is currently underway in Ontario, and an ivory gull (*Pagophila eburnea*), a designated species of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC, 2003), have been killed by these wires. The presence of dead Caspian terns (*Sterna caspia*) beneath these transmission lines also warrants concern owing to this species' population status both in Ontario and U.S. states bordering the Great Lakes (Kress et al., 1983; Blokpoel and Scharf, 1991; Neuman and Blokpoel, 1997). A further reason for conservation concerns when birds strike transmission lines is the increased risk of disease transmission, such as avian botulism if carcasses are not removed frequently (Malcolm, 1982).

For those surveys where age of dead or injured birds was determined, we most often found a higher proportion of juvenile birds being affected by the wires (Table 4). While some studies have shown that young, inexperienced birds strike wires more frequently (McNeil et al., 1985; Brown et al., 1987; Crivelli et al., 1988; Morkill and Anderson, 1991), other studies have found that adults are more vulnerable to collisions than juveniles (Anderson, 1978). Henderson et al. (1996) reported changes in flight behaviour around power lines by adult common terns (*Sterna hirundo*) during four phases of their breeding season, and that juvenile terns flew consistently closer to the lines than adults.

Have bird deaths decreased as a result of the installation of bird flight diverters above Burlington beach? This question cannot be answered conclusively by looking at the data collected during the years covered by this paper. The numbers of dead birds found on Burlington beach decreased in the years following the installation (Table 1), however, the utilization of outside organizations to report on dead birds could be biased by inexperience and/or different amounts of search efforts in different years, before or after the bird flight diverters were installed.

Search bias, removal bias, habitat bias and crippling bias were not calculated during the years reported in this paper (APLIC, 1994; Bevanger, 1999). The wide variety of habitats beneath the lines may mean that some dead birds are not being recovered, while others may be scavenged by predators, or removed by adjacent land owners. As portions of these lines extend over Lake Ontario, some carcasses may fall into the water and not be censused. Therefore, the count data reported in this paper should be assumed to be minimum numbers of birds being affected by these lines. Future work at these study locations should involve the utilization of experienced observers for data collection with experiments conducted to measure some of the biases mentioned above.

CONCLUSIONS

The transmission lines above Burlington and Hamilton, Ontario beaches are negatively affecting a number of migratory bird species. Bird deaths appear to have declined since bird flight diverters were placed on the lines above Burlington beach, however, more rigorous surveys will be necessary to determine if bird mortality has truly decreased at marked versus unmarked transmission lines. Future research at these locations should include observations on bird use over this transmission right-of-way (species, numbers, and behaviour towards lines), standardized searches for dead and injured birds, along with observer error and scavenger removal experiments.

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REFERENCES

Anderson, W.L. 1978. Waterfowl collisions with power lines at a coal-fired power plant. Wildlife Society Bulletin, 6: 77–83.

Alonso, J.A. and J.C. Alonso. 1999. Mitigation of bird collisions with transmission lines through groundwire marking. In: M. Ferrer, and G.F.E. Janss (Eds.). Birds and Power Lines: Collision, Electrocution and Breeding. Quercus Publishing Co., Spain. pp. 113–124.

APLIC (Avian Power Line Interaction Committee). 1994. Mitigating bird collisions with power lines: The state of the art in 1994. Edison Electric Institute, Washington, DC. 78 pp.

Bevanger, K. 1994. Bird interactions with utility structures: collision and electrocution, causes and mitigating measures. Ibis, 136: 412–425.

Bevanger, K. 1998. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation, 86: 67–76.

Bevanger, K. 1999. Estimating bird mortality caused by collision and electrocution with power lines; a review of methodology. In: M. Ferrer, and G.F.E. Janss (Eds.). Birds and Power Lines: Collision, Electrocution and Breeding. Quercus Publishing Co., Spain. pp. 29–56.

Blokpoel, H. and W.C. Scharf. 1991. Status and conservation of seabirds nesting in the Great Lakes of North America. In: Croxall, J.P. (Ed.). International Council for Bird Preservation Technical Publication No. 11. pp. 17–41.

Blokpoel, H. and G.D. Tessier. 1996. Atlas of colonial waterbirds nesting on the Canadian Great Lakes. Part 3. Cormorants, gulls and island-nesting terns on the lower Great Lakes system in 1990. Canadian Wildlife Service-Ontario Region, Technical Report No. 225, Ottawa, Ontario. 74 pp.

Brown, W.M. and R.C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. Wildlife Society Bulletin, 23: 217–227.

Brown, W.M., R.C. Drewien, and E.G. Bizeau. 1987. Mortality of cranes and waterfowl from powerline collisions in the San Luis Valley, Colorado. In: J.C. Lewis (Ed.). Proceedings of the 1985 Crane Workshop. Platte River Whooping Crane Maintenance Trust, Grand Island, Nebraska. pp. 128–136.

Corcoran, L.M. 1999. Migratory Bird Treaty Act: strict criminal liability for non-hunting, human caused bird deaths. Denver University Law Review, 77: 315–358.

COSEWIC (Committee on the Status of Wildlife in Canada). 2003. COSEWIC assessment results, November 2003. Committee on the Status of Wildlife in Canada, Ottawa, Ontario. 44 pp.

Coues, E. 1876. The destruction of birds by telegraph wires. American Naturalist, 10: 734–736.

Crivelli, A.J., H. Jerrentrup, and T. Mitchev. 1988. Electric power lines: a cause of mortality in *Pelecanus crispus* Bruch, a world endangered bird species, in Porto-Lago, Greece. Colonial Waterbirds, 11: 301–305.

Crowder, M.R. and O.E. Rhodes, Jr. 2002. Relationships between wing morphology and behavioural responses to unmarked power transmission lines. In: Goodrich-Mahoney, J.W., D.F. Mutrie and C.A. Guild (Eds.). Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. Elsevier Science Ltd. pp. 403–410.

De La Zerda, S. and L. Rosselli. 2002. Mitigating collision of birds against transmission lines in wetland areas in Columbia, by marking the ground wire with bird flight diverters (BFD). In: Goodrich-Mahoney, J.W., D.F. Mutrie and C.A. Guild (Eds.). Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. Elsevier Science Ltd. pp. 395–402.

Deng, J. and P. Frederick. 2001. Nocturnal flight behaviour of waterbirds in close proximity to a transmission powerline in the Florida Everglades. Waterbirds, 24: 419–424.

Dobos, R.Z., J. Struger, H. Blokpoel, and D.V. Weseloh. 1988. The status of colonial waterbirds nesting at Hamilton Harbour, Lake Ontario, 1959–1987. Ontario Birds, 6: 51–60.

Emerson, W.O. 1904. Destruction of birds by wires. Condor, 6: 37–38.

Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, K.J. Sernka, and R.E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, Washington, DC. 62 pp.

Faanes, C.A. 1987. Bird behaviour and mortality in relation to power lines in prairie habitats. U.S. Fish and Wildlife Service General Technical Report 7, Washington, DC. 24 pp.

Ferrer, M. and G.F.E. Janss (Eds.). 1999. Birds and Power Lines: Collision, Electrocution and Breeding. Quercus Publishing Co., Spain. 239 pp.

Gebauer, M.B., R.Z. Dobos, and D.V. Weseloh. 1992. Waterbird surveys at Hamilton Harbour, Lake Ontario, 1985–1988. Journal of Great Lakes Research, 18: 420–439.

Gebauer, M.B., R.Z. Dobos, and D.V. Weseloh. 1993. Historical review of waterbird populations and annotated list of waterbirds associated with Burlington Bay, Lake Ontario. Canadian Wildlife Service Occasional Paper No. 78, Burlington, Ontario. 44 pp.

Hatch, J.J. and D.V. Weseloh. 1999. Double-crested cormorant (*Phalacrocorax auritus*). In: A. Poole and F. Gill (Eds.). The Birds of North America, No. 441. The Birds of North America Inc., Philadelphia, PA. 36 pp.

Hebert, E., and E. Reese. 1995. Avian collision and electrocution: an annotated bibliography. California Energy Commission, Publication No: P700-95-001, Sacramento, CA. 113 pp.

Henderson, I.G., R.H.W. Langston, and N.A. Clark. 1996. The response of common terns *Sterna hirundo* to power lines: an assessment of risk in relation to breeding commitment, age and wind speed. Biological Conservation, 77: 185–192.

Janss, G.F.E. 2000. Avian mortality from power lines: a morphologic approach of a species-specific mortality. Biological Conservation, 95: 353–359.

Janss, G.F.E. and M. Ferrer. 1998. Rate of bird collision with power lines: effects of conductor-marking and static wire- marking. Journal of Field Ornithology, 69: 8–17.

Kerlinger, P. 2000. Avian mortality at communication towers: a review of recent literature, research and methodology. Unpublished report prepared for the U.S. Fish and Wildlife Service, Office of Migratory Bird Management, Washington, DC. 38 pp.

Klem, D., Jr. 1990. Bird injuries, cause of death, and recuperation from collisions with windows. J. Field Ornithology, 61: 115–119.

Koops, F.B.J. 1987. Collision victims of high-tension lines in the Netherlands and effects of marking. KEMA Report 01282-MOB 86-3048.

Kress, S.W., E.H. Weinstein, and I.C.T. Nisbet. 1983. The status of tern populations in the northeastern United States and adjacent Canada. Colonial Waterbirds, 6: 84–106.

Lewis, J.C. 1993. The U.S. Fish and Wildlife Service and bird-power line interactions. In: J.W. Huckabee (Ed.). Proceedings: Avian Interactions with Utility Structures, International Workshop, September 13–16, 1992, Miami, FL. pp. 2-1 – 2-6.

Malcolm, J.M. 1982. Bird collisions with a power transmission line and their relation to botulism at a Montana wetland. Wildlife Society Bulletin, 10: 297–304.

Manville, A.M., II. 2001a. The ABCs of avoiding bird collisions at communication towers: next steps. In: R.L. Carlton (Ed.). Avian Interactions with Utility and Communication Structures. Proceedings of a workshop held in Charleston, South Carolina, December 2–3, 1999, EPRI Technical Report, Concord, CA. pp. 85–103.

Manville, A.M., II. 2001b. Avian mortality at communication towers: steps to alleviate a growing problem. In: B.B. Levitt (Ed.). Cell Towers: Wireless Convenience? or Environmental Hazard? Proceedings of the Cell Towers Forum, State of the Science/State of the Law, New Century Publishing 2000, Markham, Ontario. pp. 75–86.

Manville, A.M., II. 2002. Bird strikes and electrocutions at power lines, communication towers, and wind turbines: state of the art and state of the science – next steps toward mitigation. 3rd International Partners in Flight Conference, Asilomar State Park Conference Centre, Monterey, CA.

McNeil, R., J.R. Rodriguez, and H. Ouellet. 1985. Bird mortality at a power transmission line in northeastern Venezuela. Biological Conservation, 31: 153–165.

Moore, D.J., H. Blokpoel, K.P. Lampman, and D.V. Weseloh. 1995. Status, ecology and management of colonial waterbirds nesting in Hamilton Harbour, Lake Ontario, 1988–1994. Canadian Wildlife Service-Ontario Region, Technical Report No. 213, Burlington, Ontario. 38 pp.

Morkill, A. D. and S. H. Anderson. 1991. Effectiveness of marking power lines to reduce sandhill crane collisions. Wildlife Society Bulletin, 19: 442–449.

Morris, R.D., C. Pekarik, D.V. Weseloh, and J.S. Quinn. 2001. Progress toward colonial waterbird population targets in Hamilton Harbour (1998–2000). Ontario Birds, 19: 12–25.

Neuman, J. and H. Blokpoel. 1997. The terns of the Canadian Great Lakes. Environment Canada Great Lakes Fact Sheet. Government of Canada, Downsview, Ontario. 16 pp.

Pekarik, C., A.N. Nicassio, H. Blokpoel, D.V. Weseloh, J. Hall, S. Fink, C. Anderson, and J.S. Quinn. 1997. Management of colonial waterbirds nesting in Hamilton Harbour: the first two years of colonization of artificial islands and population trends. Canadian Wildlife Service-Ontario Region, Technical Report No. 287, Burlington, Ontario. 38 pp.

Raevel, P. and J.C. Tombal. 1991. Impact des lignes haute-tension sur l'avifaune. Les Cahiers de L'A.M.B.E. Aménagement et Environnement, Vol. 2. 31 pp.

Savereno, A.J., L.A. Savereno, R. Boettcher, and S.M. Haig. 1996. Avian behavior and mortality at power lines in coastal South Carolina. Wildlife Society Bulletin, 24: 636–648.

Thompson, L.S. 1978. Mitigation through engineering and habitat modification. In: M.L. Avery (Ed.). Impacts of Transmission Lines on Birds in Flight. U.S. Fish and Wildlife Service, Washington, DC. pp. 51–92.

Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Canadian Wildlife Service, Ontario Region, Ottawa. 85 pp.

BIOGRAPHICAL SKETCHES

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Small Mammal Communities along Transmission Power Line Rights-of-Way in Deciduous Forests of Québec

Christian Fortin and G. Jean Doucet

In 1995, TransÉnergie initiated a research program on biodiversity in high voltage powerline rights-of-way (ROWs) in Québec (Canada). As part of this study, small mammals were trapped in two deciduous forest sites of southern Québec. Our objective was to compare small mammal communities between a managed (Windsor area, 2001–2003) and a non-managed (La Conception, 2002–2003) ROW and between the ROW and the adjacent forest of both sites. The managed ROW has been plowed, levelled out, and sowed with grass and leguminous species at initial clearing in 1989 whereas the non-managed ROW has been let to itself as original clearing. For each study site, four trapping transects were marked at 15 m intervals from the middle of the ROW to 90 m into the forest. Each transect was divided into four habitats representing the ROW, the edge, the shallow woods, and the deep woods. Traps were run for 5 consecutive days in July and August. A total of 170 small mammals (10 species) were captured in La Conception whereas 331 small mammals (9 species) were captured in Windsor. Common shrew, meadow vole, and short-tailed shrew were the dominant species in both ROWs. Pygmy shrew, southern bog lemming, and smoky shrew, three uncommon species in Québec, were also captured in the ROWs. The relative abundance of all small mammals combined, species richness, and species diversity (Shannon index) were similar among the four habitats in both sites. The relative abundance of most species did not differ among the four habitats. Exceptions involved meadow jumping mouse, which was most abundant in the edge and in the ROW in Windsor, and *Peromyscus* spp, which was least abundant in the ROW in Windsor. Nine species were captured in the ROW of both managed and non-managed sites. The abundance of all small mammal species combined was significantly higher in the ROW of La Conception than in the Windsor ROW, as in the other three habitats. Species richness and species diversity in the ROW were higher in La Conception compared to Windsor in 2003 but were similar in 2002. The latter observation may have resulted from the mechanical cutting of woody vegetation in the ROW in La Conception in the fall of 2002. We conclude that small mammal communities appear robust to ROW creation, maintenance, and management in the deciduous forest of southern Québec.

Keywords: Small mammals, right-of-way, deciduous forest, abundance, species richness, species diversity, Québec, right-of-way

INTRODUCTION

Effects of human disturbances on abundance, diversity, and dynamics of small mammals have been studied extensively (Oxley et al., 1974; Richardson et al., 1997; Hadley and Wilson, 2004), especially those related to clearcutting (Kirkland, 1990; Yahner, 1992; Gagné et al., 1999; Hayward et al., 1999; Potvin et al., 1999; Darveau et al., 2001; de Bellefeuille et al., 2001; Moses and Boutin, 2001). Edge effects have been of special concern (Sekgororoane and Dilworth, 1995; Bayne and Hobson, 1998; Pasitschniak-Arts and Messier, 1998; Menzel et al., 1999). In general, small mammal populations appear robust to forest management (Kirkland, 1990; Bowman et al., 2001b).

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

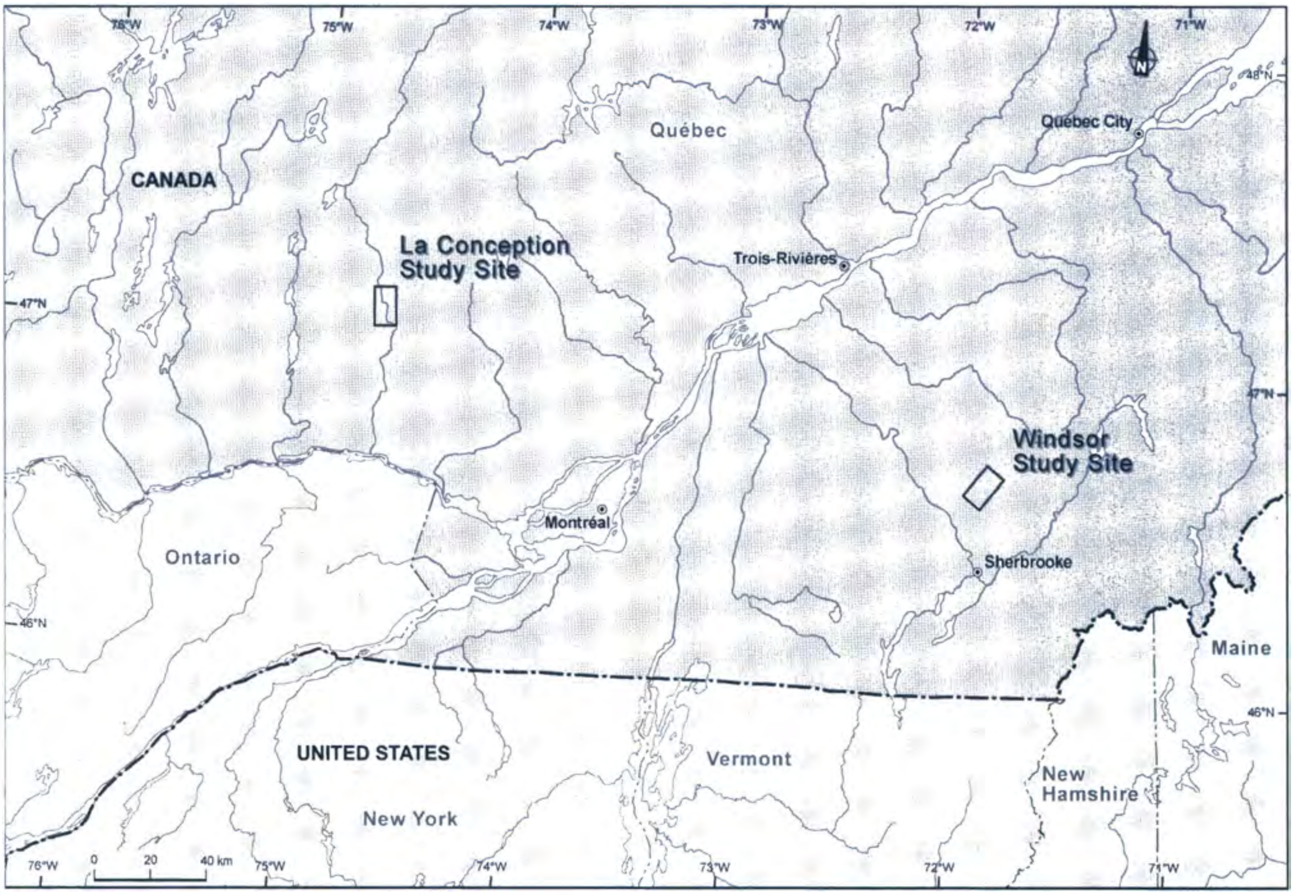

Fig. 1. Location of the two study sites in Québec, Canada.

Powerline right-of-way (ROW) clearing represents, as clearcutting, an important anthropogenic disturbance and few studies have evaluated their impacts on small mammals. ROWs differ mainly from clearcuts in that they are never allowed to develop to maturity due to regular vegetation maintenance. Powerline corridors seemingly do not prevent movements of small mammals across the landscape (Schreiber and Graves, 1977; Bramwell, 1980), and small mammal abundance is similar or even higher in ROWs compared to adjacent forests (Johnson et al., 1979; Bélisle et al., 2002; Bramble et al., 1992; Fortin and Doucet, 2003). Goldingay and Whelan (1997) showed that powerline corridors do not create edge effects in eucalypt forest of Australia for two native small mammal species. In addition, Doucet and Bider (1984) observed that clear-cut and debris removal immediately following an experimental clearing of a forested right-of-way contributed to a decrease in activity for small mammals.

Some segments of the ROW network in southern Québec have been managed at initial clearing to delay shrub and tree invasion (Lefebvre and Lussier, 1993). Effects of such management on small mammal abundance and diversity are poorly documented. In this paper, we report small mammal abundance, richness, and diversity between ROW and adjacent forest at two study sites and compare these variables between a managed and a non-managed ROW. Our study is part of a larger program examining biodiversity in high voltage powerline ROWs in Québec (Deshaye et al., 1996; 2000; Fortin et al., 2003).

STUDY AREA AND METHODS

Study sites

Data were collected from two study sites located in the deciduous forest of southern Québec, Canada (Fig. 1; Fortin et al., 2003). The two ROWs studied were characterized by a different background or history and are referred to as "managed" and "non-managed" ROW. The term managed ROW is used by TransÉnergie to describe ROWs in which at initial clearing the stumps were pulled out, the ground graded to improve drainage and the entire ROW planted with a seed mixture to retard invasion by woody plants. A non-managed ROW represents a ROW where the initial clearing consisted of cutting all woody stems, leaving all stumps in place and the ground to natural conditions. The non-managed ROW (120 m wide) is situated near the town of La Conception (46°10′N, 74°44′W) and harbours two 735 kV transmission lines established in 1978. ROW topography is uneven and altitude varies between 210 and 350 m in the study area. The ROW has been let to itself at original clearing. Because of periodic mechanical cutting of woody vegetation, this ROW is maintained in a herbaceous-shrub condition with scattered saplings. Segments of the corridor were cut in the fall of 2002. The ROW vegetation in 2002–2003 was dominated by *Acer rubrum* (coverage = 20.0%), *Acer saccharum* (14.2%), *Aralia nudicaulis* (11.6%), *Asclepias syriaca* (11.6%), *Calamagrostis canadensis* (15.0%), *Maianthemum canadense* (15.3%), *Rubus pubescens* (14.7%), *Solidago rugosa* (10.0%), and *Vicia cracca* (19.2%). Mature forest occurs all along the study site and is composed mainly of *Abies balsamea* (54.2%), *Acer rubrum* (30.8%), *Acer saccharum* (82.5%), *Aralia nudicaulis* (11.7%), *Betula lutea* (11.3%), *Fagus grandifolia* (40.4%), and *Maianthemum canadense* (22.5%).

The managed ROW (60–90 m wide) is located near the town of Windsor (45°35′N, 71°50′W). The 450 kV transmission line was established in 1989. ROW topography is uniform and altitude varies between 260 and 300 m in the study area. The corridor has been plowed, levelled out, and sowed with grass and leguminous species at initial clearing (Doucet et al., 1997). Since, native and alien species have invaded the right-of-way. The ROW vegetation in 2001–2002 was composed mainly of *Acer rubrum* (16.6%), *Anaphalis margaritacea* (17.7%), *Betula lutea* (12.8%), *Calamagrostis canadensis* (13.3%), *Carex debilis* (10.1%), *Phleum pratense* (40.4%), *Solidago canadensis* (36.0%), and *Solidago rugosa* (44.6%). The forest adjacent to the ROW presents different successional stages and is dominated by *Abies balsamea* (17.7%), *Acer pensylvanicum* (27.8%), *Acer rubrum* (46.7%), *Acer saccharum* (41.2%), *Betula lutea* (33.3%), *Coptis groenlandica* (12.7%), *Fagus grandifolia* (23.5%), *Maianthemum canadense* (18.5%), *Trientalis borealis* (16.2%), and *Tsuga canadensis* (16.3%).

Trapping design

Trapping was carried out along four transects (at each study site) established perpendicular to the powerline (Fig. 2). Transects were selected to be representative of the study sites and were separated from each other by at least 750 m. All were located on one side of the ROW. These were marked at 15 m intervals from the middle of the ROW to 90 m into the forest, giving 12 trapping stations per transect. At each trapping station, 5 traps (three Victor traps and two 2 l plastic pitfalls) were set 5 m apart perpendicular to the transect. Snap traps were baited with peanut butter and pitfalls were filled with 10 cm of water. Traps were set for five consecutive days at the end of July in La Conception, and at the beginning of August in Windsor. Individuals were identified to the species using external criteria and tooth patterns (Lupien, 2000; 2002). *Peromyscus leucopus* and *Peromyscus maniculatus* were not differentiated.

Data analysis

Each transect was divided into four habitats: the ROW, the edge, the shallow woods (stations situated at 15, 30, and 45 m from the edge), and the deep woods (60, 75, and 90 m from the edge). The relative abundance of small mammals was defined as the number of captures per 100 trap-nights, with correction for sprung traps (Nelson and Clark, 1973). Species richness is the number of species trapped, and species diversity was calculated using the Shannon–Wiener index (Krebs, 1989). An analysis of variance model (two factorial randomized block design) was used to study the effect of year and habitat on the relative abundance, species richness, and species diversity, the transect being the block. For the comparison of the two study sites, a third factor was incorporated into the model. Each ANOVA was performed on the relative abundance of all species combined and for the most common species separately. The GLM procedure of SAS was used to perform the analyses (SAS Institute, 1999). When the assumption of homogeneity of variance or the normality assumption was not met, the square root transformation was applied to the raw data.

RESULTS

Overall capture success

A total of 170 small mammals were captured during 1810.5 trap-nights (both trap types) in La Conception in 2002–2003 (Table 1). Ten species were captured, but 70% of captures were short-tailed shrew, masked shrew, and red-backed vole. Southern bog lemming and pygmy shrew, two uncommon species in Québec, were also captured in the ROW. In Windsor, 331 small mammals were captured during 2972 trap-nights from 2001–2003 (Table 1). Nine species were captured, and four species represented more than 12% of total captures: masked shrew, *Peromyscus*, red-backed vole, and short-tailed shrew. Pygmy shrew and smoky shrew, two uncommon species in Québec, were also captured in the ROW.

Relative abundance of all species combined

When we analyzed the study sites separately, overall mean relative abundance of small mammals (Table 2) was similar between habitats in La Conception ($P = 0.68$) and Windsor ($P = 0.31$). We did not detect a significant difference in the total numbers of small mammals caught in La Conception among years ($P = 0.33$). However, there was significant variation among years in Windsor ($P < 0.00001$), with more animals caught in 2001 than 2002 or 2003. When the study site was incorporated into the model (2002 and 2003 data only), the abundance of small mammals did not differ between habitat ($P = 0.09$) but significant differences were observed between sites ($P = 0.02$), with higher abundance in La Conception than in Windsor in all habitats (no site-habitat interaction).

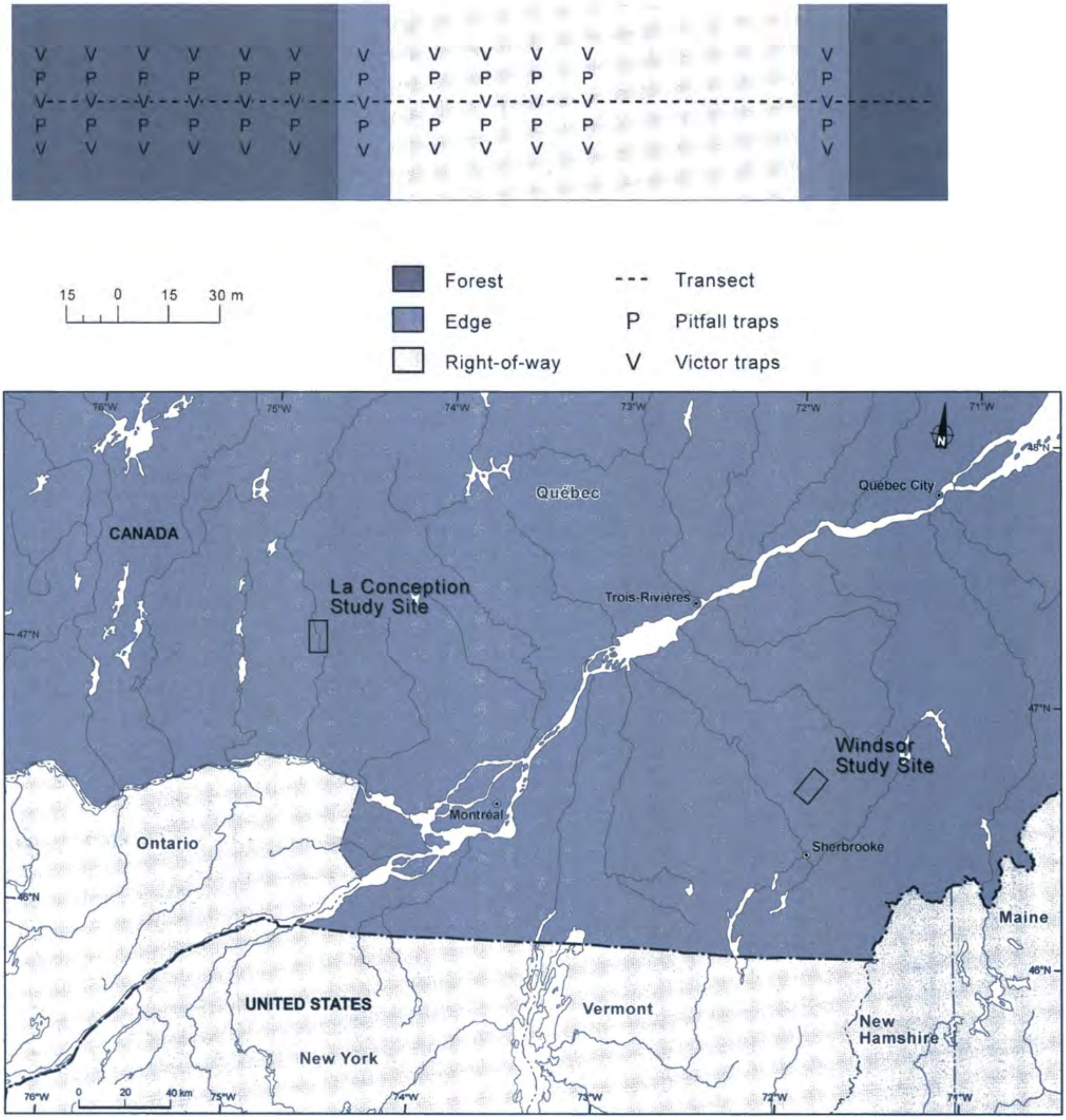

Fig. 2. Trapping design.

Relative abundance for most common species

The relative abundance of red-backed vole, *Peromyscus*, short-tailed shrew, and masked shrew did not vary significantly among habitats in La Conception (2002 and 2003 combined; Table 3). Similarly, the abundance of red-backed vole, short-tailed shrew, masked shrew, meadow vole, and woodland jumping mouse did not differ significantly in Windsor (2001–2003 combined). However, *Peromyscus* was significantly less abundant in the ROW than in the other three habitats in Windsor, and meadow jumping mouse was significantly more abundant in the ROW and edge at Windsor than in shallow and deep woods. When the study site was incorporated into the model (2002 and 2003 data only), short-tailed shrew abundance did not vary significantly between sites ($P = 0.13$) and habitats ($P = 0.79$). Capture success of masked shrew was similar between sites ($P = 0.37$) but differed significantly between habitats ($P = 0.04$), with higher abundance at edge.

Species richness

Overall, nine species were captured in the ROW of both study sites. When we analyzed the sites separately (Table 4), species richness was similar between habitats in La Conception ($P = 0.27$) and Windsor ($P = 0.64$). Species richness did not vary sig-

Table 1. Number of individuals of each species captured in La Conception and Windsor, Québec

Species	Study site	La Conception			Windsor			
	Year	2002	2003	Total	2001	2002	2003	Total
	Trap-nights	925.5	885.0	1810.5	1007.0	1018.5	946.5	2972.0
Red-backed vole *Clethrionomys gapperi*		8	13	**21**	25	0	17	**42**
Meadow vole *Microtus pennsylvanicus*		4	4	**8**	26	0	5	**31**
Southern bog lemming *Synaptomys cooperi*		0	1	**1**	0	0	0	**0**
Meadow jumping mouse *Zapus hudsonius*		0	3	**3**	18	2	4	**24**
Woodland jumping mouse *Napaeozapus insignis*		7	3	**10**	13	2	13	**28**
Deer mouse/white-footed mouse *Peromyscus* spp		3	9	**12**	42	2	13	**57**
Masked shrew *Sorex cinereus*		16	26	**42**	71	12	7	**90**
Short-tailed shrew *Blarina brevicauda*		28	28	**56**	10	15	15	**40**
Pygmy shrew *Sorex hoyi*		2	2	**4**	5	2	0	**7**
Smoky shrew *Sorex fumeus*		8	4	**12**	3	1	0	**4**
Unidentified		0	1	**1**	3	1	4	**8**
Total		**76**	**94**	**170**	**216**	**37**	**78**	**331**

Table 2. Mean relative abundance (number per 100 trap-nights) of all small mammals combined in four habitats of La Conception and Windsor, Québec

Study site	Year	Habitat							
		ROW		Edge		Shallow wood		Deep wood	
		Mean $N=4$	Std	Mean $N=4$	Std	Mean $N=4$	Std	Mean $N=4$	Std
La Conception	2002	6.7	3.8	9.9	10.8	10.1	4.6	7.3	2.5
	2003	11.3	3.7	13.4	5.2	8.7	2.7	9.3	7.0
Windsor	2001	24.1	19.4	25.0	13.4	16.6	5.6	21.8	19.7
	2002	3.6	1.8	7.7	4.8	2.6	2.2	1.7	0
	2003	3.2	1.6	10.8	3.0	8.0	3.8	11.8	3.1

Table 3. Mean relative abundance (number per 100 trap-nights) of small mammals in four habitats of La Conception (2002, 2003) and Windsor (2001–2003), Québec

Species/habitat	La Conception					Windsor				
	ROW	Edge	Shallow wood	Deep wood	*P*	ROW	Edge	Shallow wood	Deep wood	*P*
Traps-nights	634.5	288.5	436	451.5		1099.5	466.5	706	700	
Red-backed vole	0.3	0.7	1.2	2.7	0.23	0.5	0.9	1.8	2.9	0.07
Peromyscus spp	0.3	1.1	0.9	0.6	0.35	0.3	1.9	3.3	3.0	**0.003**
Short-tailed shrew	3.3	3.4	3.7	2.0	0.87	1.5	2.4	0.4	1.4	0.12
Masked shrew	2.4	3.9	1.8	1.8	0.29	3.0	5.6	1.7	3.1	0.17
Meadow vole	1.3	0	0	0	–	2.3	0.4	0.1	0.3	0.11
Woodland jumping mouse	0.8	0.4	0.2	0.7	–	0.7	1.5	1.0	0.9	0.81
Meadow jumping mouse	0.3	0	0	0	–	1.5	1.5	0.3	0	**0.02**
Pygmy shrew	0.2	0	0.5	0.2	–	0.3	0	0.4	0.1	–
Smoky shrew	0	2.1	1.2	0.2	–	0.3	0.2	0	0	–
Southern bog lemming	0.2	0	0	0	–	0	0	0	0	–

Table 4. Mean measures of species richness in four habitats of La Conception and Windsor, Québec

	Year					
	2001		2002		2003	
	Mean $N=4$	Std	Mean $N=4$	Std	Mean $N=4$	Std
La Conception						
ROW	–	–	2.25	0.96	4.25	1.26
Edge	–	–	1.75	0.96	2.00	0.82
Shallow wood	–	–	3.00	1.16	2.50	0.58
Deep wood	–	–	3.50	1.29	2.75	2.06
Windsor						
ROW	5.50	1.73	2.00	0.82	2.00	1.16
Edge	4.00	1.41	1.50	0.58	3.50	0.58
Shallow wood	3.75	1.71	1.25	0.96	3.00	0.82
Deep wood	4.00	2.16	1.00	0	3.75	1.26

Table 5. *P* values for site-habitat-year effect sliced by habitat-year for species richness

Habitat	Year	DF	*F* value	*P*
ROW	2002	1	0.12	0.74
ROW	2003	1	9.35	**0.005**
Edge	2002	1	0.12	0.74
Edge	2003	1	4.15	**0.05**
Shallow wood	2002	1	5.65	**0.03**
Shallow wood	2003	1	0.46	0.50
Deep wood	2002	1	11.54	**0.002**
Deep wood	2003	1	1.85	0.19

(ANOVA, three-factorial randomized block design)

nificantly among years in La Conception ($P = 0.55$) but differed significantly among years in Windsor ($P < 0.00001$; 2001 > 2003 > 2002). When the study site was incorporated into the model (2002 and 2003 data only), site-habitat-year interaction occurred ($P = 0.007$). Species richness in the ROW was similar among sites in 2002 but was higher in La Conception in 2003 (Table 5). Species richness in the edge was similar among sites in 2002 and 2003, while species richness in the shallow and deep woods were similar among sites in 2003 but higher in La Conception in 2002.

Species diversity

When we analyzed the study sites separately (Table 6), species diversity (Shannon index) was similar between habitats in La Conception ($P = 0.15$) and Windsor ($P = 0.64$). Species diversity did not differ significantly among years in La Conception ($P = 0.67$) but varied significantly among years in Windsor ($P < 0.00001$; 2001 = 2003 > 2002). When the study site was incorporated into the model (2002 and 2003 data only), site-habitat-year interaction occurred ($P = 0.01$). As with species richness, species diversity in the ROW was similar among sites in 2002 but was higher in La Conception in 2003 (Table 7). Species diversity in the edge was similar among sites in 2002 and higher in Windsor in 2003, while species diversity in the shallow

Table 6. Mean measures of Shannon index in four habitats of La Conception and Windsor, Québec

	Year					
	2001		2002		2003	
	Mean $N=4$	Std	Mean $N=4$	Std	Mean $N=4$	Std
La Conception						
ROW	–	–	0.70	0.49	1.31	0.32
Edge	–	–	0.43	0.52	0.51	0.40
Shallow wood	–	–	0.95	0.34	0.86	0.22
Deep wood	–	–	1.17	0.41	0.85	0.60
Windsor						
ROW	1.42	0.29	0.59	0.43	0.53	0.62
Edge	1.18	0.35	0.30	0.35	1.19	0.16
Shallow wood	1.06	0.52	0.33	0.39	0.99	0.26
Deep wood	1.12	0.40	0	0	1.08	0.45

Table 7. *P* values for site-habitat-year effect sliced by habitat-year for the Shannon index

Habitat	Year	DF	*F* value	*P*
ROW	2002	1	0.12	0.73
ROW	2003	1	6.72	**0.02**
Edge	2002	1	0.20	0.66
Edge	2003	1	5.19	**0.03**
Shallow wood	2002	1	4.32	**0.05**
Shallow wood	2003	1	0.21	0.65
Deep wood	2002	1	15.21	**0.0007**
Deep wood	2003	1	0.59	0.45

(ANOVA, three-factorial randomized block design)

and deep woods were similar among sites in 2003 but higher in La Conception in 2002.

DISCUSSION

Small mammal community along the ROW/forest gradient

Overall, small mammals appeared to respond positively to the creation and maintenance of ROWs in the deciduous forest of southern Québec. Relative abundance of all species combined, species richness, and the Shannon index were similar between the four habitats in both sites. Similarly, the relative abundance was similar among habitats or higher in the ROW in 6 of the 7 common species. Johnson et al. (1979), Bélisle et al. (2002), Bramble et al. (1992), and Fortin and Doucet (2003) also found that small mammal diversity is similar or greater in ROWs compared to adjacent forests. However, our results apply only at the stand scale. The presence of additional powerlines in the same corridor could result in an overall decline in landscape diversity due to habitat fragmentation (Johnson et al., 1979). The impacts of electric transmission ROW on diversity need to be studied at both stand and regional scales (Johnson et al., 1979; Bowman et al., 2001a; Martin and McComb, 2002).

Those observations reflect the resource generalism of many small mammal species occurring in our study areas, as observed by Kirkland (1990) and Bowman et al. (2001b) in managed forests. All species collected during our study were captured at least once in the ROW. Woodland jumping mouse primarily occurs in woods but it is also commonly found in shrubs and forest edges (Whitaker and Wrigley, 1972), as we observed. The two most abundant species noted during our study, short-tailed shrew and masked shrew, are habitat generalists (George et al., 1986; Parker, 1989; Menzel et al., 1999) and were equally captured in all habitats when we analyzed the study sites separately. When the site factor was incorporated into the model, short-tailed shrew abundance still remained similar between the habitats but masked shrew was most abundant at the edge. Menzel et al. (1999) also noted that abundance of masked shrew was highest along the edge in hardwood communities of western North Carolina.

Vegetation maintenance interventions constitute another factor that may contribute to maintain high small mammal diversity in ROWs. Regular vegetation maintenance had promoted an herbaceous understory community in the La Conception ROW, which may have favoured the presence of species associated with this habitat. Kirkland (1990) observed that a portion of the increase in small mammal abundance on many clearcuts is attributable to exploitation of such sites by non-forest small mammals, particularly *Microtus* and *Zapus*. In our study sites, where herbaceous cover is dominant in ROWs, *Zapus hudsonius* abundance was higher in the ROW and edge. *Microtus pennsylvanicus* abundance seemed also higher in the ROW, although larger sample sizes are needed to confirm these results. Fortin and Doucet (2003) found a similar pattern along a twin 315 kV transmission powerline right-of-way (95 m wide) in the boreal forest of Québec. Those observations are not surprising since meadow vole and meadow jumping mouse are strongly associated with open habitats such as meadows, grasslands, and openings (Banfield, 1977; Nagorsen and Peterson, 1981; Reich, 1981).

In contrast, red-backed vole was most abundant in forest than in ROW, approaching statistical significance in Windsor ($P = 0.07$) but not in La Conception ($P = 0.23$). Red-backed voles are forest inhabitants (Merritt, 1981), so we expect them to respond negatively to disturbance that removes forest cover (Mills, 1995; Sekgororoane and Dilworth, 1995; Menzel et al., 1999; Hadley and Wilson, 2004). Fortin and Doucet (2003) found that red-backed voles strongly avoided a 95 m wide ROW situated in the boreal forest. On the other hand, Hayward et al. (1999) found that red-backed vole did not strongly avoid the interior of small patchcuts, and Moses and Boutin (2001) observed that the abundance of *C. gapperi* on moderate-residual grids remained similar to that of unlogged grids. Thus, the response of red-backed vole to clearcut seems highly variable, and may not occur at all (Kirkland, 1990). The pattern observed in our study is somewhere in the middle of this continuum. The mechanism seems complex and remains speculative, although moisture requirements, abundance of downed woody materiel, and escape cover may be involved (Getz, 1968; Gagné et al., 1999; Carey and Harrington, 2001; Moses and Boutin, 2001).

Captures of deer mouse were less frequent in the ROW at Windsor than the other three habitats. *Peromyscus* were also shown to prefer woods over the right-of-way or edge habitats in southern Québec (Bramwell, 1980). Similarly, a review of 21 published studies by Kirkland (1990) revealed that *Peromyscus* tend to decline in abundance following clearcutting of deciduous forests. The strong association between *Peromyscus* and logging litter (Kirkland, 1990) may contribute to the responses seen in our study, as those logging residue are removed or burned prior to powerline construction. It is improbable that competitive interactions explain our findings, as neither meadow voles nor red-backed voles affect the spatial distribution or abundance of deer mice (Galindo and Krebs, 1985).

Managed versus non-managed ROW

Our results suggest that the small mammal community observed along the managed ROW of Windsor is similar to the community noted along the non-managed ROW of La Conception. Nine species were captured in both ROWs, and the three dominant species in that habitat were the same: short-tailed shrew, masked shrew, and meadow vole. When the study sites were analyzed separately, no habitat effect was detected in both sites for the relative abundance of all species combined, species richness, and species diversity. As a tentative explanation of those results, we propose a lack of obvious differences in vegetation among the ROWs. Ten years after construction, the Windsor ROW, which had been sowed with grass and leguminous plants, is now characterized by a dense ground cover of herbaceous plants, except in rocky areas where shrubs are dominant, as observed in La Conception. Only one species used in the sowing, *Phleum pratense*, is still abundant in the managed ROW. In fact, both managed ($n = 238$) and non-managed ($n = 200$) ROWs supported similar plant species richness (Fortin et al., 2003). Woody debris are rare in both sites.

When the study site was incorporated into the model, species richness and species diversity in the ROW were similar between sites in 2002 but were higher in La Conception in 2003. This may be due to the mechanical cutting of woody vegetation in two ROW transects of La Conception in the fall of 2002. Woody debris was left in the ROW, providing ground cover and moist conditions that may have enhanced habitat quality for species reluctant to use the ROWs.

For example, red-backed vole and *Peromyscus*, two species associated with forest stands during our study, were absent from transect 3 of La Conception in 2002 where the ROW was dominated by a tall shrubby habitat, but were observed in this location in 2003. Further investigations are needed to understand the responses of small mammals to the new, but ephemeral habitat created by woody residues left in the ROW after vegetation maintenance.

Study limitations

The results of our study should be interpreted with caution. The study was done in markedly different locations and in ROWs of different ages and maintenance procedures. Small mammal community in the ROW may be different in the first few years following ROW construction compared to our study sites where ROW are of intermediate ages (11 and 24 years old). Similarly, different cover types produced by various treatments (handcutting, herbicide, mowing) may influence small mammals abundance and diversity (Bramble et al., 1992).

Results from other studies show that when herbicides are not used, woody and non woody vegetation grow very rapidly after a vegetation control treatment in a ROW, and somewhat regardless of the type of treatment. This can create a difficulty when comparing small mammals catch results from ROWs with different treatment, as the similarity of the vegetation structure limits the usefulness of this variable to interpret the results, through a confounding effect.

Capture data obtained from removal-trapping may not accurately represent true small mammal composition because of trapping biases (Sullivan et al., 2003; Nicolas et al., 2003). However, as trapping methods used in our study were standard among the habitats and sites, we think that these data can be used for inter-habitat and site comparisons.

Because we did not examine demographic indices of the small mammal species, we can not conclusively infer if the utilization of ROW we observed reflects a similar habitat quality compared to the edge and forest for small mammals. Source-sink scenarios (Pulliam, 1988), where individuals primarily born in forest migrate into ROW to breed, but where the probabilities for winter survival are poor, may occur. Studies evaluating winter survival and reproduction of small mammals in ROWs would greatly enhance our comprehension of population dynamics in this particular habitat for this group of species.

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REFERENCES

Banfield, A.W.F. 1977. Les mammifères du Canada. Musée national des sciences, Musées nationaux du Canada. Les Presses de l'Université Laval, Ste-Foy, Québec.

Bayne, E.M., and K.A. Hobson. 1998. The effects of habitat fragmentation by forestry and agriculture on the abundance of small mammals in the southern boreal mixed wood forest. Canadian Journal of Zoology, 76: 62–69.

Bélisle, F., G.J. Doucet, and Y. Garant. 2002. Wildlife use of riparian vegetation buffer zones in high voltage powerline rights-of-way in the Québec boreal forest. In: Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management. J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild, eds. Elsevier Science. Oxford. Pp. 309–317.

Bowman, J., C.V. Corkum, and G.J. Forbes. 2001a. Spatial scales of trapping in small-mammal research. Canadian Field-Naturalist, 115: 472–474.

Bowman, J., G. Forbes, and T. Dilworth. 2001b. Landscape context and small-mammal abundance in a managed forest. Forest Ecology and Management, 140: 249–255.

Bramble, W.C., R.H. Yahner, W.R. Byrnes, and S.A. Liscinsky. 1992. Small mammals in plant cover types on an electric transmission right-of-way. Journal of Arboriculture, 18: 316–321.

Bramwell, R.N. 1980. Animal activity, weather and vegetation control along a Quebec powerline right-of-way. MSc Thesis. McGill University, Montréal, Québec.

Carey, A.B., and C.A. Harrington. 2001. Small mammals in young forests: implications for management for sustainability. Forest Ecology and Management, 154: 289–309.

Darveau, M., P. Labbé, P. Beauchesne, L. Bélanger, and J. Huot. 2001. The use of riparian forest strips by small mammals in a boreal balsam fir forest. Forest Ecology and Management, 143: 95–104.

De Bellefeuille, S., N. Gagné, L. Boulanger, J. Huot, A. Simon, S. Déry, and J.-P. Jetté. 2001. Effets de trois scénarios de régénération de la sapinière boréale sur les passereaux nicheurs, les petits mammifères et le lièvre d'Amérique. Canadian Journal of Forest Research, 31: 1312–1325.

Deshaye, J., J. Brunelle, and F. Morneau. 1996. Étude de la biodiversité des emprises de lignes de transport d'énergie électrique en forêt mixte. Rapport pour la vice-présidence Environnement et Collectivités, Hydro-Québec. FORAMEC, Québec, Québec.

Deshaye, J., C. Fortin, and F. Morneau. 2000. Caractérisation de la biodiversité dans les emprises de transport d'énergie électrique situées en forêt boréale. Années 1998–2000. Rapport pour TransÉnergie. FORAMEC, Québec, Québec.

Doucet, G.J., and J.R. Bider. 1984. Changes in animal activity immediately following the experimental clearing of a forested right-of-way. In: Proceedings 3rd Symposiun on Environmental Concerns in Rights-of-Way Management. Crabtree, A.F., ed. Mississippi State University. Pp. 592–601.

Doucet, G.J., Y. Garant, M. Giguère, and G. Philip de Laborie. 1997. Emprises de lignes et ravages de cerfs de Virginie, Tome 1. Synthèse et bilan des études. TransÉnergie, Hydro-Québec, Montréal, Québec.

Fortin, C., and G.J. Doucet. 2003. Communautés de micromammifères le long d'une emprise de lignes de transport d'énergie électrique située en forêt boréale. Naturaliste Canadien, 127(2): 47–53.

Fortin, C., F. Morneau, J. Deshaye, P. Galois, and M. Ouellet. 2003. Caractérisation de la biodiversité des emprises de lignes de transport d'énergie électrique situées en forêt décidue. Rapport d'ensemble 2001–2003 pour TransÉnergie. FORAMEC, Québec, Québec.

Gagné, N., L. Bélanger, and J. Huot. 1999. Comparative responses of small mammals, vegetation, and food sources to natural regeneration and conifer release treatments in boreal balsam fir stands of Québec. Canadian Journal of Forest Research, 29: 1128–1140.

Galindo, C., and C.J. Krebs. 1985. Habitat use and abundance of deer mice: interactions with meadow voles and red-backed voles. Canadian Journal of Zoology, 63: 1870–1879.

George, S.B., J.R. Choate, and H.H. Genoways. 1986. *Blarina brevicauda*. Mammalian Species, 261: 1–9. Getz, L.L. 1968. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology, 49: 276–286.

Getz, L.L. 1968. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology, 49: 276–286.

Goldingay, R.L., and R.J. Whelan. 1997. Powerline easements: do they promote edge effects in eucalypt forest for small mammals? Wildlife Research, 24: 737–744.

Hadley, G.L., and K.R. Wilson. 2004. Patterns of density and survival in small mammals in ski runs and adjacent forest patches. Journal of Wildlife Management, 68: 288–298.

Hayward, G.D., S.H. Henry, and L.F. Ruggiero. 1999. Response of red-backed voles to recent patch cutting in subalpine forest. Conservation Biology, 13: 168–176.

Johnson, W.C., R.K. Schreiber, and R.L. Burgess. 1979. Diversity of small mammals in a powerline right-of-way and adjacent forest in east Tennessee. American Midland Naturalist, 101: 231–235.

Kirkland Jr., G.L. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. Oikos, 59: 313–320.

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York, New York.

Lefebvre, Y., and G. Lussier. 1993. Bilan de l'aménagement de l'emprise. Ligne à 450 kV Radisson-Nicolet-Des Cantons. Hydro-Québec, Équipements de Transport.

Lupien, G. 2000. Recueil photographique des caractéristiques morphologiques servant à l'identification des micromammifères du Québec. Volume 1. Insectivores. Société de la faune et des parcs du Québec, Jonquière, Québec.

Lupien, G. 2002. Recueil photographique des caractéristiques morphologiques servant à l'identification des micromammifères du Québec. Volume 2. Rongeurs. Société de la faune et des parcs du Québec, Jonquière, Québec.

Martin, K.J., and W.C. McComb. 2002. Small mammal habitat associations at patch and landscape scales in Oregon. Forest Science, 48: 255–264.

Menzel, M.A., W.M. Ford, J. Laerm, and D. Krishon. 1999. Forest to wildlife opening: habitat gradient analysis among small mammals in the southern Appalachians. Forest Ecology and Management, 114: 227–232.

Merritt, J.F. 1981. *Clethrionomys gapperi*. Mammalian Species, 146: 1–9.

Mills, L.S. 1995. Edge effect and isolation: red-backed voles on forest remnants. Conservation Biology, 9: 395–403.

Moses, R.A., and S. Boutin. 2001. The influence of clear-cut logging and residual leave material on small mammal populations in aspen-dominated boreal mixedwoods. Canadian Journal of Forest Research, 31: 483–495.

Nagorsen, D.W., and R.L. Peterson. 1981. Distribution, abundance and species diversity of small mammals in Quetico Provincial Park, Ontario. Naturaliste Canadien, 108: 209–218.

Nelson, L., and F.W. Clark. 1973. Correction for sprung traps in catch/effort calculations of trapping results. Journal of Mammalogy, 54: 295–298.

Nicolas, V., P. Barrière, and M. Colyn. 2003. Impact of removal pitfall trapping on the community of shrews (Mammalia: Soricidae) in two African tropical forest sites. Mammalia, 67: 133–138.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology, 11: 51–59.

Parker, G.R. 1989. Effects of reforestation upon small mammal communities in New Brunswick. Canadian Field-Naturalist, 103: 509–519.

Pasitschniak-Arts, M., and F. Messier. 1998. Effects of edges and habitats on small mammals in a prairie ecosystem. Canadian Journal of Zoology, 76: 2020–2025.

Potvin, F., R. Courtois, and L. Bélanger. 1999. Short-term response of wildlife to clear-cutting in Quebec boreal forest: multiscale effects and management implications. Canadian Journal of Forest Research, 29: 1120–1127.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist, 132: 652–661.

Reich, L.M. 1981. *Microtus pennsylvanicus*. Mammalian Species, 159: 1–8.

Richardson, J.H., R.F. Shore, and J.R. Treweek. 1997. Are major roads a barrier to small mammals? Journal of Zoology, 243: 840–846.

SAS Institute. 1999. SAS/STAT User's Guide, version 8. SAS Institute, Cary, North Carolina.

Schreiber, R.K., and J.H. Graves. 1977. Powerline corridors as possible barriers to the movements of small mammals. The American Midland Naturalist, 97: 504–508.

Sekgororoane, G.B., and T.G. Dilworth. 1995. Relative abundance, richness, and diversity of small mammals at induced forest edges. Canadian Journal of Zoology, 73: 1432–1437.

Sullivan, T.P., D.S. Sullivan, D.B. Ransome, and P.M.F. Lindgren. 2003. Impact of removal-trapping on abundance and diversity attributes in small-mammal communities. Wildlife Society Bulletin, 31: 464–474.

Whitaker, J.O., and R.E. Wrigley. 1972. *Napaeozapus insignis*. Mammalian Species, 14: 1–6.

Yahner, R.H. 1992. Dynamics of a small mammal community in a fragmented forest. American Midland Naturalist, 127: 381–391.

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Wildlife use of Riparian Vegetation Buffer Zones in High Voltage Powerline Rights-of-Way in Quebec Deciduous Forest

A. Bérubé, M. Larose, M. Belles-Isles, and G.J. Doucet

TransÉnergie operates a network of approximately 33,000 km of high voltage powerlines in Quebec. Over 8,000 vegetation buffer zones are located in these rights-of-way, mainly to protect stream habitats. These riparian buffers are made up of woody vegetation strips about 10 m wide, which span the width of the right-of-way. The objective of the study was to compare wildlife activity in riparian vegetation buffer zones of transmission powerline rights-of-way to that of adjacent habitat in the southern Quebec deciduous forest. Fieldwork was conducted during the spring and summer of 2002 and 2003 in the Laurentians–Lanaudière regions. A total of 39 buffers located in rights-of-way were sampled for small mammals, birds, and anurans. Bird and anuran calls were sampled using automatic tape recorders. Small mammals and anurans were sampled using snap traps and pitfall traps. Vegetation in buffer zones consisted of a low stratum with a high stem density and small mean diameter at breast height (DBH). The herbaceous stratum in buffer zones was more developed than in the adjacent forest. The latter was characterized by a high vegetation stratum, lower stem density and a large mean DBH. Results tend to show higher bird species richness in buffers, but the occurrence probability is higher for species recorded in the adjacent forest. American toad and Northern spring peeper were heard in both habitats. The occurrence probability of the Northern spring peeper was higher in buffers compared to that in adjacent forest. A total of 690 specimens belonging to 13 species of small mammals were captured for a trapping effort of 8,256 trap-nights. Abundance of small mammals was similar in buffers and adjacent forest. Overall, results indicate a high species richness in buffer zones. These results suggest it would be appropriate to adopt a prudent management strategy, which promotes the conservation of shrubby and herbaceous strata in these riparian right-of-way habitats.

Keywords: Buffer zones, small mammals, anurans, birds, biodiversity, species richness, powerline, right-of-way

INTRODUCTION

Hydro-Québec operates a network of 33,000 km of high voltage powerlines throughout Quebec, including about 5,000 km of rights-of-way in the deciduous forest. We estimate that in the entire network, well over 8,000 buffer zones made up of woody vegetation, about 10 m wide spanning the width of the right-of-way are in place. The majority of these buffer zones were left in place when the rights-of-way were originally cleared. It was assumed that such buffer zones would protect streams from soil erosion and siltation while maintaining physical characteristics of both aquatic and riparian habitats. In recent years, it has been postulated that buffer zones in rights-of-way could be important habitats (ex. corridors) for the groups of species targeted by this study. This is mainly related to the fact that the animal communities are richer in the deciduous forest than in the mixed or boreal forests (Bélisle et al., 2002). The objective of the study was to compare wildlife activity, such as small mammals, birds, and anurans, in riparian vegetation buffer zones in relatively wide transmission powerline rights-of-way to that in riparian habitats in the adjacent deciduous forest.

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STUDY AREA

Fieldwork was carried out in the Quebec deciduous forest, more precisely in the Laurentians lowlands (45°56′00″N–73°34′00″W) and Lanaudière regions (46°14′30″N–73°51′30″W) approximately 55 km of each other. In 2002, most sampling sites were located in the Lanaudière region, between the towns of Saint-Anne-des-Plaines and Saint-Michel-des-Saints, while a few were located in the Lower Laurentians (line 7016). In 2003, sampling sites were all located in the Lower Laurentians, between Lachute and L'Ascension (lines 7044 and 7045).

METHODS

Activity schedule

The elaboration of the study protocol and the choice of the study area, was conducted in 2001. The study design and the preliminary selection of the sampling sites were conducted in 2001. Fieldwork was conducted in the summers of 2002 and 2003. For both summers, a total of 39 sites were sampled for vegetation and small mammals, whereas 8 sites were sampled in spring 2002 for birds and anurans.

Sampling sites description

For the purpose of the study, suitable sampling sites were defined as a segment of right-of-way easily accessible from the ground, and crossing a stream lined on each side by a buffer zone, 10 m wide, and composed of residual woody vegetation. Each site was composed of a buffer and a control zone. The buffer zone was made up by the 10 m wide vegetation strips left in place, on both sides, along the stream crossed by the right-of-way. Controls had the same dimensions as the buffer zones, and were located 150 to 200 m from the right-of-way edge. Control sites were also located on each side of streams in non-disturbed woody areas (Fig. 1).

Vegetation structure

The vegetation structure was evaluated at 2 sampling stations in both buffer and control zones in 39 sites. To qualitatively and quantitatively characterize vegetation structure in both buffer and control, 3 sampling methods were used: the point intercept method, the diameter at breast height (DBH) and a vegetation profile board. Low vegetation composition (<1 m high) was measured using a modified point intercept (Barbour et al., 1987; Jonasson, 1988). Using this method, vegetation classes (deciduous shrubs, coniferous shrubs, herbs, bare ground, mosses and woody debris, etc.) were identified at all intersection points within a table grid (50 × 50 cm) containing 36 intersection points. High vegetation composition (>1 m high) was determined by measuring DBH of each tree in the sampling station. Lateral vegetation density was measured using a vegetation profile board 2 m high by 0.3 m wide divided into 4 rectangles 0.5 m in height. An observer standing 15 m north and south of the board estimated the percentage of lateral visual obstruction. For each rectangle, the percentage of obstruction was recorded using 5 classes (0–20%; 21–40%; 41–60%; 61–80%; 81–100%).

Small mammals

Small mammals were trapped in 39 sites using Museum Special traps, Victor Mouse traps, and pitfall

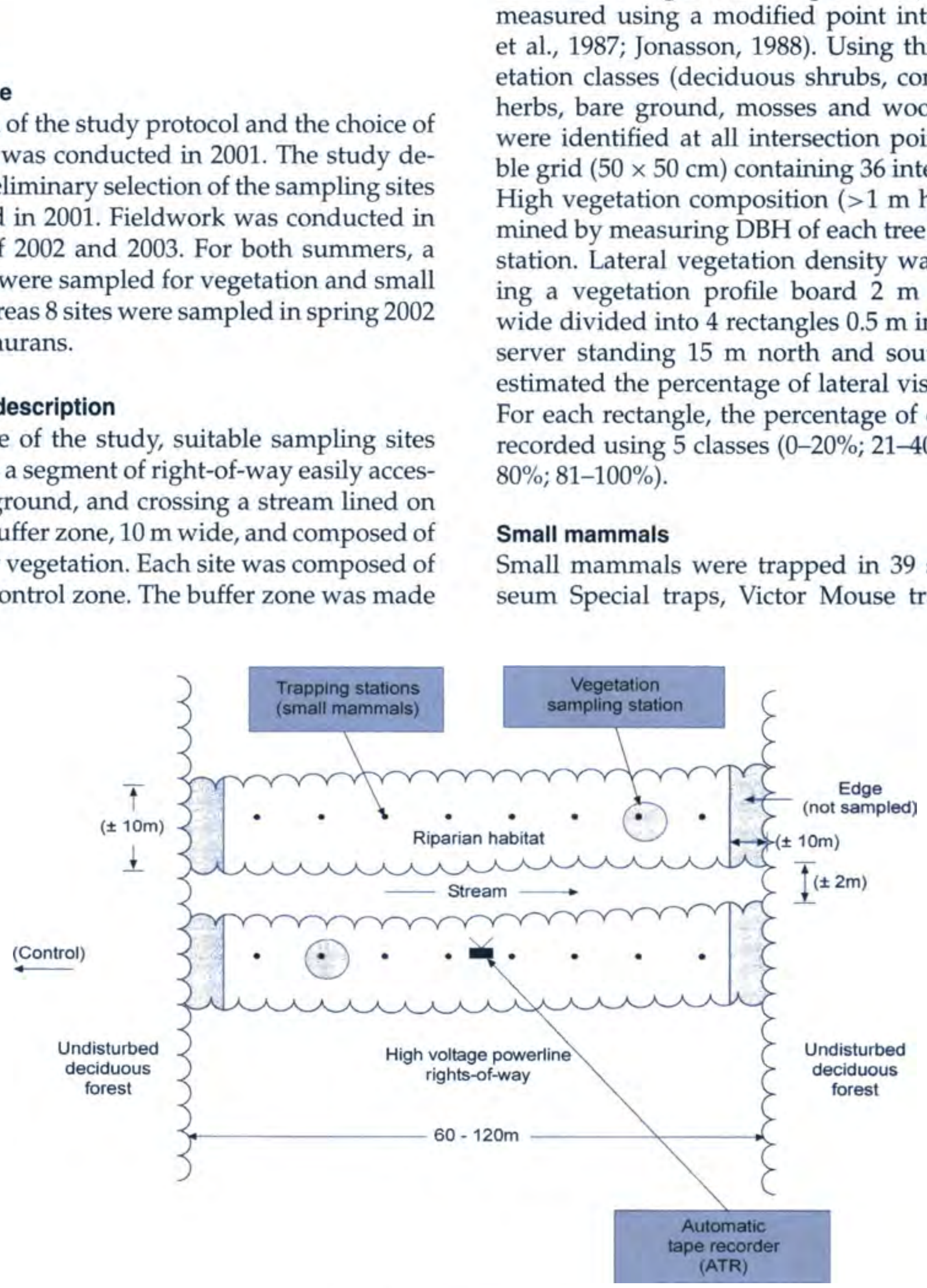

Fig. 1. Study design.

traps (2L plastic containers) distributed along linear transects, parallel to the stream, in the middle of the riparian habitat. Museum Special traps and Victor Mouse traps were baited with peanut butter and oatmeal. Sampling stations were set 10 m apart in such a manner as to cover the entire width of the right-of-way. In both buffer and control zones, 16 trapping stations were positioned (8 on each side of the stream) along transects. At each trapping station, both types of snap traps (Museum Special and Victor) were placed less than 1 m from each other. Pitfall traps were set every 5 sites at the same trapping stations as snap traps. They were filled with water, approximately 5 to 10 cm, and set with the opening at ground level.

In 2002, 1,280 snap traps were set at 20 sites whereas in 2003, 1,216 snap traps were set at 19 sites. For both sampling years, 128 pitfall traps were spread into 4 sampling sites. All types of traps were set for 3 successive nights and visited every day for a total of 8,256 trap-nights; 4,224 in 2002 and 4,032 in 2003. Small mammals were identified to the species level and total body mass was determined for each specimen captured.

Birds and anurans

Automatic tape recorders (ATR) coupled to a programmable timer were set in buffer and control zones to record bird and anuran vocal calls from dawn to dusk. Recording stations were installed in the middle of each zone (buffer and control) for 3 successive days. Vocal calls were recorded synchronously in both zones during three 3-minute periods distributed between 2 recording sessions, for a total of 18 minutes of listening per day. A first recording session occurred in the morning (5h00 to 7h03) and a second one in the evening (19h40 to 21h43). Since calls emitted over 60 m from the automatic tape recorder were hardly identifiable (Bélisle et al., 2002), it was assumed that recorders in buffer zones would not detect vocal calls in controls, since both recorders were located at least 150 m away from each other.

Data analysis

Comparison analyses between buffer and control zones considered these 2 habitats to be within a complete random block. Data on low vegetation structure were expressed as percent cover by vegetation classes. Data on high vegetation structure were expressed as the number of woody stems/40 m^2 for each vegetation class and each DBH. Data on lateral visual obstruction were expressed as mean percentage (%) by height levels for north and south sides and for total height of the board. Data on vegetation height, relative abundance of small mammals (capture/100 trap-nights), and total body mass of specimens captured were compared using ANOVA. The Shannon index was used to compare vegetation and small mammal species diversity between buffer and control zones and was calculated as follow:

$$H = \frac{n \log n - \sum fi \log fi}{n}$$

where H = Shannon index; n = number of small mammals captured in one stratum, and fi = number of small mammals of species i captured in the same stratum.

Bird and anuran calls were computed as number of 3-minute periods with at least 1 call heard for one species. This procedure was established to minimize the bias of counting a high number of individuals for a given species without knowing if calls were emitted by one or many individuals. Vocal activity was expressed as occurrence probability (% of chance for a given species to be heard during a 3-minute period). Data were analyzed for dominant species to compare vocal activity between buffer and control zones using a LOGIT model (McCullagh and Nelder, 1989).

RESULTS

Vegetation structure

The low vegetation stratum in buffer zones is mainly composed of herbaceous species (72.97%) and of young deciduous shrubs (13.78%) (Table 1). Herbaceous density is significantly higher in buffer zones compared to controls (ANOVA, $p < 0.001$). The high vegetation stratum is mainly composed of shrubs with diameters ranging from 0.5 to 3 cm (35.18 stems/40 m^2). Conifers are poorly represented in buffer zones. Indeed, the deciduous cover (34.63 stems/40 m^2) shows a diameter ranging from 0.5 to 3 cm, and is more important in buffer than in control (ANOVA, $p < 0.001$). These high densities of herbaceous plants and deciduous shrubs in buffer zones offer a strong lateral visual obstruction from the ground to 2 m high, which is higher than what is observed in controls (ANOVA, $p = 0.001$ to 0.027). The dominance of herbaceous and low shrub strata offers a lower vegetation mean height in buffers compared to controls (ANOVA, $p < 0.001$).

The lower vegetation stratum in controls is also mainly composed of herbaceous species (41.40%) and deciduous shrubs (16.74%). Woody debris and bare ground, however, are significantly higher than in buffer zones. It indicates the presence of mature forest communities, showing some scattered low vegetation areas. Significantly lower lateral visual obstruction measurements in controls confirm this observation. In controls, as in buffer zones, the high vegetation stratum is mainly composed of shrubs with a diameter between 0.5 and 3 cm (15.71 stems/40 m^2), and most of them are deciduous (14.10 stems/40 m^2). Conifers, however, are more present in controls compared to buffer zones (ANOVA, $p = 0.002$), in spite of a low density of this group (3.24 stems/40 m^2). Furthermore, when all species are taken together, stems with

Table 1. Comparison of vegetation structure measured in 2002–2003 (mean ± SE) between buffer and control zones; underlined values are significantly higher (ANOVA, $p < 0.01$, $n = 39$ sites). DBH = diameter at breast height

	Row				
	Buffer zone		Control		P value
Low vegetation stratum (<0.5 m height)	**(% of ground cover)**				
Coniferous shrubs	1.00	±4.88	0.78	±2.25	0.804
Deciduous shrubs	13.78	±18.56	16.74	±17.07	0.473
Herbaceous	72.97	±25.69	41.40	±32.47	<0.001
Moss	1.78	±5.27	3.03	±5.55	0.273
Bare ground	4.06	±10.91	21.15	±25.53	0.001
Woody debris	6.52	±11.25	14.40	±19.28	0.023
High vegetation stratum (>0.5 m height)	**(stems/40 m^2)**				
All species and DBH	38.94	±24.66	24.22	±17.18	0.002
All species (0.5 to 3 cm DBH)	35.18	±25.05	15.71	±12.51	<0.001
All species (3.1 to 7 cm DBH)	3.19	±5.84	6.56	±7.17	0.037
All species (7.1 cm and over DBH)	0.51	±1.36	1.95	±2.13	0.001
Coniferous cover (all DBH)	0.95	±1.64	3.24	±4.38	0.002
Coniferous cover (0.5 to 3 cm DBH)	0.55	±0.86	1.60	±2.62	0.019
Coniferous cover (3.1 to 7 cm DBH)	0.24	±0.65	0.92	±1.43	0.007
Coniferous cover (7.1 cm and over DBH)	0.15	±0.55	0.94	±1.98	0.024
Deciduous cover (all DBH)	37.94	±25.10	20.97	±17.28	<0.001
Deciduous cover (0.5 to 3 cm DBH)	34.63	±25.25	14.10	±12.12	<0.001
Deciduous cover (3.1 to 7 cm DBH)	2.95	±5.57	5.64	±7.20	0.085
Deciduous cover (7.1 cm and over DBH)	0.36	±0.96	1.23	±1.08	0.001
Specific richness	**(index)**				
Shannon	0.41	±0.29	0.54	±0.22	0.008
Lateral visual obstruction	**(% of visual obstruction)**				
From ground up to 2 m height	71.43	±16.74	58.06	±16.38	0.002
Ground to 0.5 m height	77.43	±18.62	62.89	1 26.09	0.003
From 0.5 to 1.0 m height	72.37	±18.26	54.87	±20.52	0.001
From 1.0 to 1.5 m height	67.24	±24.87	54.87	±18.54	0.013
From 1.5 to 2.0 m height	68.68	±28.44	59.61	1 23.86	0.027
Vegetation height	**(m)**				
Visual mean height of vegetation in habitat	6.14	±7.97	23.29	±10.53	<0.001

a greater diameter (≥ 3.1 cm) are significantly more abundant in controls (ANOVA, $p = 0.001$). Vegetation maximal height in controls (23.29 m) is about 4 times greater than in buffer zones. Finally, on the basis of the 32 woody species encountered, the Shannon index value was significantly higher in controls (ANOVA, $p = 0.008$).

Small mammals

During the summers of 2002 and 2003, we captured 690 small mammals for a trapping effort of 8,256 trap-nights. Capture efficiency was about 2 times higher in 2003 for an overall efficiency of 8.36 captures/100 trap-nights. Although diversity tends to be higher in buffer zones, the Shannon index is not significantly different between buffer zones and controls (Table 2). Woodland jumping mouse, meadow jumping mouse, deer mouse and northern short-tailed shrew were the 4 most abundant species and accounted for 81% of the total number of small mammals captured (Table 3). When considering all species, small mammal relative abundance in buffer zones (8.37 captures/100 trap-nights) is similar to controls (8.91 captures/100 trap-nights) (ANOVA, $p = 0.688$). In short, species diversity of small mammals and capture probability are not significantly different between upper and lower strata.

Table 2. Comparison of small mammals species richness (Shannon index) measured in 2002–2003 between buffer and control zones; underlined values are significantly higher (ANOVA, $p < 0.01$, $n = 39$ sites)

Index	Row				
	Buffer zone		Control		P value
Shannon (diversity)	0.432	±0.184	0.376	±0.172	0.197

During the summers of 2002 and 2003, 13 species of small mammals were captured. Twelve in buffer zones and 10 in controls (Table 4). Meadow jumping mouse (2.22 captures/100 trap-nights), northern short-tailed shrew (1.25 capture/trap-nights), meadow vole (0.56 capture/100 trap-nights) and southern bog lemming (0.26 capture/trap-nights) were significantly more abundant in buffer zones (ANOVA, $p < 0.05$).

Table 3. Comparison of small mammal relative abundance (capture/100 trap-nights) measured in 2002–2003 (mean ± SE(n)) between buffer and control zones; underlined values are significantly higher (ANOVA, $p < 0.01$, $n = 39$ sites)

Species	Row						
	N	Buffer zone		N	Control		P value
Northern short-tailed shrew (*Blarina brevicauda*)	50	1.25	±1.43	25	0.61	±0.89	0.022
Red-backed vole (*Clethrionomys gapperi*)	11	0.27	±0.49	48	1.17	±2.34	0.025
Southern flying squirrel (*Glaucomys volans*)	0	0.00	±0.00	2	0.04	±0.19	0.165
Smoky shrew (*Sorex fumeus*)	1	0.02	±0.15	1	0.02	±0.15	–
Meadow vole (*Microtus pensylvanicus*)	23	0.56	±1.19	8	0.20	±0.59	0.029
Woodland jumping mouse (*Napaeozapus insignis*)	121	2.97	±3.97	156	3.71	±5.30	0.312
Deer mouse (*Peromyscus maniculatus*)	14	0.35	±0.92	77	1.88	±4.00	0.019
Masked shrew (*Sorex cinereus*)	13	0.30	±0.64	8	0.19	±0.44	0.303
Water shrew (*Sorex palustris*)	1	0.02	±0.15	0	0.00	±0.00	0.324
Southern bog lemming (*Synaptomys cooperi*)	10	0.26	±0.78	0	0.00	±0.00	0.044
Red squirrel (*Tamiasciurus hudsonicus*)	1	0.02	±0.11	0	0.00	±0.00	0.324
Eastern chipmunk (*Tamias striatus*)	2	0.05	±0.22	2	0.05	±0.21	0.964
Meadow jumping mouse (*Zapus hudsonius*)	90	2.22	±2.60	26	0.61	±1.47	<0.0001
All species	337	8.37	±5.88	353	8.91	±9.68	0.688

Table 4. Comparison of mean body mass (g ± SE) of the more abundant small mammal species captured in 2002–2003 between buffer and control zones (ANOVA, $p < 0.01$, $n = 39$ sites)

Species	Row						
	N	Buffer zone		N	Control		P value
Northern short-tailed shrew (*Blarina brevicauda*)	50	20.96	±3.32	25	21.00	±4.72	0.976
Red-backed vole (*Clethrionomys gapperi*)	11	25.88	±10.20	48	21.00	±1.47	0.435
Meadow vole (*Microtus pensylvanicus*)	23	31.79	±1.94	8	28.50	±14.46	0.760
Woodland jumping mouse (*Napaeozapus insignis*)	121	21.05	±3.89	156	21.83	±3.11	0.519
Deer mouse (*Peromyscus maniculatus*)	14	21.00	±6.28	77	18.09	±2.92	0.519
Meadow jumping mouse (*Zapus hudsonius*)	90	16.73	±3.79	26	17.02	±6.63	0.914

On the other hand, red-backed vole (1.17 capture/100 trap-nights) and deer mouse (1.88 capture/100 trap-nights) showed a significantly higher abundance in controls (ANOVA, $p < 0.05$). Interestingly, woodland jumping mouse presented a high abundance in both buffer and control zones, without showing any significant differences between them (2.97 and 3.71 captures/100 trap-nights, respectively; ANOVA, $p = 0.312$). For the 6 species captured in greatest number, mean mass analysis did not show any significant difference between buffer and control zones (Table 4; ANOVA, $p = 0.435$ to 0.976).

Birds

Vocal activity recorded by ATR allowed identifying 41 bird species in buffer zones and 31 in controls, while 28 species were common to both zones. White-throated sparrow, American robin, hermit thrush, winter wren and American crow were the 5 most frequently heard species (Table 5). Thirteen bird species were recorded only in buffer zones, whereas 3 species were recorded only in controls. Most of these species (8 in buffers and 1 in controls) were recorded only once. Occurrence probabilities of black-throated green warbler, ovenbird and yellow-bellied sapsucker were 3 times greater in controls than in buffer zones. These occurrence probabilities, however, were not significantly different between both strata (Table 6; LOGIT model, $p > 0.05$).

Anurans

Northern spring peeper was the anuran species most frequently recorded. Call activities of this species were recorded along 94 periods of 3 minutes in buffer zones and 45 periods in controls (Table 5). Occurrence probability of Northern spring peeper was almost 2 times higher in buffer zones (Table 6). There was a significant difference, however, between both strata (LOGIT model, $p = 0.096$). American toad calls were also heard in both buffer and control zones, during 5 periods of 3 minutes in buffer zones and 2 periods in controls.

DISCUSSION

Many studies maintain that riparian buffer zones are important habitats for several species. In southern Quebec, riparian habitats are used by 80% of all reptile species, 60% of all mammals and anurans, and over 40% of nesting birds (Vandal and Huot, 1978 In Maisonneuve and Rioux, 2001). In addition to preventing soil erosion, and to filter some contaminating substances and sedimentary particles, riparian buffer zones maintain habitat quality by contributing notably

Table 5. Comparison of vocal activity (3-minute periods with at least 1 vocal call heard for one given species) for all bird and anuran vocal calls heard between buffer and control zones ($n = 8$ sites)

Species	Row	
	Buffer zone	Control
Birds		
White-throated sparrow (*Zonotrichia albicollis*)	100	71
American robin (*Turdus migratorius*)	36	42
Hermit thrush (*Catharus guttatus*)	13	24
Winter wren (*Troglodytes troglodytes*)	18	17
American crow (*Corvus brachyrhynchos*)	20	14
Black-capped chickadee (*Parus atricapilus*)	19	9
Veery (*Catharus fuscescens*)	13	10
Ovenbird (*Seiurus aurocapillus*)	5	18
Nashville warbler (*Vermivora ruficapilla*)	13	8
Red-winged blackbird (*Agelaius phoeniceus*)	13	7
Black-throated green warbler (*Dendroica virens*)	5	14
Solitary vireo (*Vireo solitarius*)	9	9
Yellow-rumped warbler (*Dendroica coronata*)	11	6
Blue jay (*Cyanocitta cristata*)	7	5
Yellow-bellied sapsucker (*Sphyrapicus varius*)	3	9
Black-and-white warbler (*Mniotilta varia*)	3	8
American goldfinch (*Carduelis tristis*)	5	2
Least flycatcher (*Empidonax minimus*)	1	6
Purple finch (*Carpodacus purpureus*)	6	1
Magnolia warbler (*Dendroica magnolia*)	3	2
Northern waterthrush (*Seiurus noveboracensis*)	2	3
Ruby-crowned kinglet (*Regulus calendula*)	3	2
Chestnut-sided warbler (*Dendroica pensylvanica*)	3	1
Common flicker (*Colaptes auratus*)	4	0
American woodcock (*Scolopax minor*)	0	3
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	3	0
Northern raven (*Corvus corax*)	3	0
Swainson's thrush (*Catharus ustulatus*)	1	3
Red-breasted nuthatch (*Sitta canadensis*)	1	2
Swamp sparrow (*Melospiza georgiana*)	2	0
Pileated woodpecker (*Dryocopus pileatus*)	1	1
Belted kingfisher (*Ceryle alcyon*)	1	1
Wilson's warbler (*Wilsonia pusilla*)	1	1
Northern parula warbler (*Parula americana*)	0	2
Common yellowthroat (*Geothlypis trichas*)	2	0
Song sparrow (*Melospiza melodia*)	1	0
White-crowned sparrow (*Zonotrichia leucophrys*)	1	0
Great horned owl (*Bubo virginianus*)	1	0
Evening grosbeak (*Coccothraustes vespertinus*)	1	0
Long-eared owl (*Asio otus*)	1	0
Blackburnian warbler (*Dendroica fusca*)	1	0
Bay-breasted warbler (*Dendroica castanea*)	1	0
Black-throated blue warbler (*Dendroica caerulescens*)	1	0
Common grackle (*Quiscalus quiscula*)	0	1
Anurans		
Northern spring peeper (*Hyla crucifer*)	94	45
American toad (*Bufo americanus*)	5	2

to water temperature regulation (Karr and Schlosser, 1978 In Maisonneuve and Rioux, 2001).

Vegetation structure

Our results show many significant vegetation structure differences between buffer and control zones. Buffer zones showed a younger vegetation structure, characteristic of ecotone, where herbaceous and deciduous shrubs dominate. On the opposite, controls showed an older community where the low vegetation stratum was less developed. These results were similar to the ones obtained in the boreal forest by Bélisle et al. (2002). Vegetation structure differences observed between buffer zones and controls explain, in part, species abundance and diversity differences in these habitats.

Small mammals

Small mammal capture efficiency was double in 2003 to that in 2002. This difference could be due to interannual population density variations. Small mammal abundance is known to show annual fluctuations (Grant, 1976 In Maisonneuve et al., 1996), and the periodicity of these fluctuations is different from one species to another. Note that sampling sites were located in two regions, relatively close to each other (Lower Laurentians vs. Lanaudière), approximately 55 km apart. Then, a part of the interannual difference observed might be caused by different distribution area or to interregional habitat characteristic differences. Vegetation analyses, however, have not detected any habitat differences between the two regions.

Woodland jumping mouse was the most abundant species captured, without any significant differences between buffer and control zones. Bélisle et al. (2002) observed a great abundance of this species in rights-of-way in the boreal forest, and no significant difference between strata. This species prefers habitats located near streams (Kirkland and Schmidt, 1982 In Maisonneuve and Rioux, 2001), in woody areas or close to forest edges (Desroches and Banville, 2002). For this species, the shrub stratum has a greater influence on spatial distribution than proximity to water (Brower and Cade, 1966 In Maisonneuve and Rioux, 2001). Furthermore, woodland jumping mouse seems strongly to be a forest specialist, but tolerant enough to habitat modifications to utilize disturbed habitats such as buffer zones, which represent a 60 to 120 m long (width of right-of-way) corridor connecting forested areas on each side of a right-of-way.

Overall, results tend to show a species segregation between buffer and control zones. In fact, 6 species showed a significant difference between upper and lower strata. Hence, meadow jumping mouse, meadow vole, northern short-tailed shrew and southern bog lemming were mainly captured in buffers whereas deer mouse and red-backed vole were more abundant in controls. Bélisle et al. (2002) observed the same distribution pattern between both strata, except for southern bog lemming. As in Bélisle et al. (2002), our results showed species composition and abundance segregations according to habitat type.

Meadow jumping mouse and meadow vole are considered specialists of open herbaceous riparian habitats, and tolerant to habitat modifications (Adler and Wilson, 1989; Maisonneuve and Rioux, 2001). Their higher abundance in buffer zones might be related

Table 6. Comparison of occurrence probability (% of chance ± SE to be heard/3-minute period) of the more abundant bird and anuran species identified between buffer and control zones (LOGIT model, $p < 0.01$, $n = 8$ sites)

Species	Row				
	Buffer zone		Control		P value
Birds					
White-throated sparrow (*Zonotrichia albicollis*)	41.9	±18.4	36.3	±10.1	0.507
Red-winged blackbird (*Agelaius phoeniceus*)	5.1	±4.8	3.6	±4.1	0.474
American crow (*Corvus brachyrhynchos*)	8.6	±7.4	6.7	±9.6	0.725
Blue jay (*Cyanocitta cristata*)	3.1	±5.5	2.6	±3.6	0.869
Veery (*Catharus fuscescens*)	2.8	±2.1	4.9	±4.2	0.307
Hermit thrush (*Catharus guttatus*)	6.9	±5.8	12.9	±17.4	0.448
American robin (*Turdus migratorius*)	14.6	±21.5	21.5	±9.9	0.332
Black capped chickadee (*Parus atricapilus*)	8.4	±7.9	4.3	±7.4	0.297
Yellow-rumped warbler (*Dendroica coronata*)	1.6	±2.8	3.1	±2.8	0.327
Black-throated green warblr (*Dendroica virens*)	1.4	±2.6	6.7	±9.2	0.182
Nashville warbler (*Vermivora ruficapilla*)	3.4	±4.7	3.9	±7.0	0.902
Ovenbird (*Seiurus aurocapillus*)	1.9	±2.6	8.8	±8.5	0.097
Black-and-white warbler (*Mniotilta varia*)	1.4	±2.6	3.8	±5.6	0.281
Yellow-bellied sapsucker (*Sphyrapicus varius*)	1.4	±1.8	5.0	±6.2	0.163
Winter wren (*Troglodytes troglodytes*)	7.1	±8.5	8.5	±8.5	0.810
Solitary vireo (*Vireo solitarius*)	4.3	±7.9	4.9	±7.2	0.761
Anurans					
Northern spring peeper (*Hyla crucifer*)	45.4	±19.5	23.0	±12.7	0.096

to the presence of a dense low vegetation structure. Northern short-tailed shrew and southern bog lemming are generalists. The northern short-tailed shrew is one of the most common small mammals in Quebec (Desroches and Banville, 2002). It is generally associated with riparian habitats (Degraaf and Yamaski, 1999 In Bélisle et al., 2002), with light soil and dense vegetation structure (Desroches and Banville, 2002). Moisture seems also to have a greater influence in habitat selection on northern short-tailed shrew (Choate and Fleharty, 1973 In Maisonneuve and Rioux, 2001). Southern bog lemming seems to show no preference between open land and forest habitats (Christian, 1999).

Finally, results show clearly a spatial segregation in relation to the type of habitat. Buffer zones are more inhabited by open lands specialist species or by generalist species. Control zones are, on the other hand, more utilized by forest specialist species intolerant to habitat modifications.

Birds

White-throated sparrow and American robin were among the most abundant species in both buffer zones and controls, similar to what Bélisle et al. (2002) observed in the boreal forest. In the present study, the occurrence probability obtained for American robin was higher in buffer zones, while in a study by Bélisle et al. (2002), it was slightly higher in controls. These observations agree with Freemark and Collins (1992) and Morneau et al. (1999), who agree that these are generalist species.

Ovenbird, black-throated green warbler, and yellow-bellied sapsucker showed an occurrence probability 3 times higher in the control stratum, even though differences between strata are not significant ($p = 0.05$). According to Lanoue and Lafontaine (1995), Drapeau and Darveau (1995), Paradis (1995) and Paquin (2003), these species can be considered to be forest habitat specialists.

Among the 16 most abundant species, 11 were heard more frequently in controls. For the most often encountered species, results seem to indicate a more regular utilization of forested controls compare to buffer zones. Bird species richness in buffer zones seems also higher compared to controls (41 species in buffers, 31 species in controls). Occurrence probabilities, however, are generally lower in buffer zones.

It is possible that birds are attracted to edges by vegetation heterogeneity, which provides a higher number of nesting and perching sites, and a greater abundance and diversity of food (Flashpohler et al., 2001). Several studies have been carried out to verify if the edge effect raised or reduced bird abundance and diversity (Morneau et al., 1999; Hannon et al., 2002; Brongo, 2002; Hanowski et al., 1995). Conclusions, however, from these studies do not always agree. Thus, some species, such as passerines, showed higher density along edges (Anderson et al., 1977; Small and Hunter, 1988; LaRue et al., 1995; Morneau et al., 1999). On the other hand, Hanowski et al. (1995) and Morneau et al. (1999) have not shown any significant differences between species richness in edge and adjacent forest.

Overall, results showed that strict forest bird species tend to have a higher occurrence probability in controls.

Anurans

Some authors state that rights-of-way tend to show a greater diversity among amphibian and reptile communities (Yahner et al., 2001). Fortin et al. (2004) observed a total of 5 urodela species, 9 anuran species and 3 snake species in powerline rights-of-way in Quebec. These 17 species represent 60% of the total biodiversity (species richness) of amphibians and reptiles of Quebec. In Pennsylvania, Yahner et al. (2001) report that rights-of-way contain a greater diversity of amphibians and reptiles than adjacent forests.

During the present study, 2 anuran species were recorded (American toad and Northern spring peeper). These 2 species did not show any significant abundance differences between buffer and control zones, as observed by Bélisle et al. (2002), even though, in both cases Northern spring peeper occurrence probability was about two times higher in buffer zones. Characteristically, buffers show a more important herbaceous and shrubby vegetation structure than controls. Also, according to Kamstra et al. (1995), American toad and Northern spring peeper are considered to be not very vulnerable to habitat disturbances related to rights-of-way. American toad is well adapted to different life conditions and is one of the most common anurans in Quebec (Desroches and Banville, 2002). Northern spring peeper is also very common in Quebec (Bider and Matte, 1994).

Overall, this study has found only 2 anuran species in buffer zones. These results, however, do not differ from what is observed in adjacent forest. Finally, occurrence probability of the most abundant species, Northern spring peeper, is almost two times higher in buffer zones to that in controls.

CONCLUSION AND MANAGEMENT IMPLICATIONS

The present study aimed at comparing wildlife activity in riparian vegetation buffer zones, indicated that wildlife activity (small mammals, birds, and anurans) is somewhat similar in buffer zones and adjacent forest in wide powerline rights-of-way in the deciduous forest. High species richness and abundance were recorded, and differences are attributable to differences in vegetation structure in the 2 habitats. We observed small mammal diversity and differences in abundance between buffer and control zones, mainly attributable to vegetation structure heterogeneity. Furthermore, greater bird species richness was recorded in buffer zones compared to controls. Overall, results, in terms of diversity and wildlife activity, are similar in the deciduous forest to those obtained by Bélisle et al. (2002) in the boreal forest.

Our study did not test specifically the necessity of maintaining buffer zones in rights-of-way for wildlife in the deciduous forest but data indicate that species richness was high in this habitat. Therefore, it would be appropriate to adopt a prudent management strategy in the maintenance of vegetation buffer zones in transmission powerline rights-of-way. Furthermore, our results do not permit conclusive statement on the importance of larger trees, we would suggest that buffers with a minimum of woody and herbaceous component be maintained at least in the low stratum. As mentioned by Bélisle et al. (2002) for the boreal forest, the structure of such buffers should include poles and saplings, along with shrubs and herbaceous species. In addition, the tallest tolerable arborescent vegetation (conductor clearance) should be maintained in ravines and deep narrow valleys.

Finally, although anuran diversity seems low per sampling sites (could be artefact of method), keeping buffer zones in rights-of-way may reduce the negative impact of habitat fragmentation. Amphibian populations appear to be cause for concern on a worldwide basis. In this context, perhaps rights-of-way can bring a modest contribution to resolve the problem. Further investigations are already planned in order to acquire more knowledge on amphibian utilization of rights-of-way. If powerline rights-of-way can maintain natural habitat attributes needed by amphibians along streams and wetlands (connectivity to breeding pools, woody debris, and cover), we hypothesize that potential negative effects on anurans could be reduced.

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REFERENCES

Adler, G.H. and M.L. Wilson. 1989. Demography of the meadow vole along a simple habitat gradient. Canadian Journal of Zoology, 67: 772–774.

Anderson, S.H., K. Mann, and H.H. Shugart, Jr. 1977. The effect of transmission-line corridors on bird populations. American Midland Naturalist, 97: 216–221.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial plant ecology. Second edition. Benjamin/Cummings publishing company Inc.

Bélisle, F., G.J. Doucet, and Y. Garant. 2002. Wildlife Use of Riparian Vegetation Buffer Zones in High Voltage Powerline Rights-of-Way in the Quebec Boreal Forest. p. 309–318. In J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild Editors. Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. Elsevier Science Ltd.

Bider, J.R. and S. Matte. 1994. Atlas of the Amphibians and Reptiles of Québec. Société d'histoire naturelle de la vallée du Saint-Laurent et ministère de l'Environnement et de la Faune du Québec, Direction de la faune et des habitats.

Brongo, D. 2002. Effets de lisières sur l'occurrence, l'activité reproductrice et le risque de prédation des nids des oiseaux chanteurs en forêt boréale mixte. Mémoire de maîtrise en biologie, Université du Québec à Montréal.

Christian, D.P. 1999. Distribution and abundance of bog lemmings (*Synaptomys cooperi* and *S. borealis*) and associated small mammals in lowland habitat in northern Minnesota (sensitive small mammals of the Chippewa National Forest). Department of Natural Resources.

Desroches, J.-F. and D. Banville. 2002. Inventaire des amphibiens, des reptiles et des micromammifères sur la côte de Beaupré en 1998. Société de la faune et des parcs du Québec.

Drapeau, P. and M. Darveau. 1995. Paruline couronnée, p. 920–923. In Gauthier, J. et Y. Aubry (sous la direction de). Les Oiseaux nicheurs du Québec: Atlas des oiseaux nicheurs du Québec méridional. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Environnement Canada, région du Québec, Montréal.

Flashpohler, D.J., S.A. Temple, and R.N. Rosenfield. 2001. Species-specific edge effects on nest success and breeding bird density in a forested landscape. Ecological Applications, 11(1): 32–46.

Fortin, C., P. Galois, M. Ouellet, and G.J. Doucet. 2004. Utilisation des emprises de lignes de transport d'énergie électrique par les amphibiens et les reptiles en forêt décidue au Québec. Le Naturaliste Canadien, 128(1): 68–75.

Freemark, K. and B. Collins. 1992. Landscape ecology of birds breeding in temperate forest fragments. Pages 443–454 *in* Ecology and conservation of neotropical migrant landbirds. *Edited by* J. M. Hagan and D.W. Johnston, Smithsonian Institution Press, Washington, D.C.

Hannon, S.J., C.A. Paszkowski, S. Boutin, J. DeGroot, S.E. MacDonald, M. Wheatley, and B.R. Eaton. 2002. Abundance and species composition of amphibians, small mammals, and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta. Canadian Journal of Forestry Research, 32: 1784–1800.

Hanowski, J.M., G.J. Niemi, and J.G. Blake. 1995. Seasonal abundance and composition of forest bird communities adjacent to a right-of-way in northern forests USA. p. 276–283. In G.J. Doucet, C. Séguin et M. Giguère Editors. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Published by Vice-présidence Environnement, Hydro-Québec.

Jonasson, S. 1988. Evaluation of the point intercept method for the estimation of plant biomass. Oikos (5): 101–106.

Kamstra, J., S. Hounsell, and W. Weller. 1995. Vulnerability of reptiles and amphibians to transmission corridors and facilities. P. 300–304. In G.J. Doucet, C. Séguin et M. Giguère Editors. Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Published by Vice-présidence Environnement, Hydro-Québec.

Lanoue, A. and P. Lafontaine. 1995. Paruline verte à gorge noire, p. 888–891. In Gauthier, J. et Y. Aubry (sous la direction de). Les Oiseaux nicheurs du Québec: Atlas des oiseaux nicheurs du Québec méridional. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Environnement Canada, région du Québec, Montréal.

LaRue, P., L. Bélanger, and J. Huot. 1995. Riparian edge effects on boreal balsam fir bird communities. Canadian Journal of Forest Research 25: 555–566.

Maisonneuve, C. and S. Rioux. 2001. Importance of riparian habitats for small mammal and herpetofaunal communities in agricultural landscapes of southern Québec. Agriculture, Ecosystems, and Environment, 83: 165–175.

Maisonneuve, C., A. Desrosiers, R. McNicoll, and M. Lepage. 1996. Évaluation de la diversité faunique des plaines inondables du sud du Québec: avifaune et micromammifères. Ministère de l'Environnement et de la Faune du Québec, direction de la faune et des habitats, Québec.

McCullagh, P. and J.A. Nelder. 1989. Generalized Linear Models, 2nd edition. Monographs on Statistics and Applied Probability, 37 Chapman and Hall, London.

Morneau, F., G.J. Doucet, M. Giguère, and M. Laperle. 1999. Breeding bird species richness associated with a powerline right-of-way in a northern mixed forest landscape. Canadian Field-Naturalist, 113(4): 598–604.

Paquin, J. 2003. *Guide photo des oiseaux du Québec et des Maritimes.* Éditions Michel Quintin, Waterloo, Québec.

Paradis, S. 1995. Pic maculé, p. 644–647. In Gauthier, J. and Y. Aubry (sous la direction de). Les Oiseaux nicheurs du Québec: Atlas des oiseaux nicheurs du Québec méridional. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Environnement Canada, région du Québec, Montréal.

Small, M.F. and M.L. Hunter. 1988. Forest fragmentation and avian predation in forested landscapes. Oecologia, 76: 62–64.

Yahner, R,H., W.C. Bramble, and W.R. Byrnes. 2001. Response of amphibian and reptile populations to vegetation maintenance of an electric transmission line right-of-way. Journal of Arboriculture, 27: 215–221.

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A Comparison of Desert Tortoise Populations along the Kern River Pipeline Right-of-Way 1991–2003

Michael Donnelly, Brent Arnold, Tim Powell, and David Schultz

The desert tortoise (Gopherus [=Xerobates] agassizii) is a federally threatened species that occurs throughout the Mojave Desert. The Mojave population of the desert tortoise has been declining in much of the region due to both direct and indirect human caused mortality. The original Kern River Pipeline was constructed in spring and summer of 1991. In the fall, winter, and spring of 2002 and 2003, the 2003 Expansion Project was completed which looped 320 miles of the existing Kern River pipeline system in the Mojave Desert in southern Utah, Nevada, and California. Data collected from field surveys and monitoring during the course of each construction project allows a unique look at the evolution of tortoise populations in the vicinity of the pipeline ROW, inclusive of a number of areas designated as critical desert tortoise habitat. Both projects required extensive desert tortoise monitoring as part of construction. Data collected during both construction projects were collected to evaluate population trends and activity levels along the entire pipeline ROW. Based on the findings, the extent of tortoise activity appears to have decreased in the project area. Tortoise encounters were significantly reduced during the winter construction season utilized by the 2003 Expansion Project, supporting an agency preference for construction timing. This information can be used as a tool by regulatory agencies and project sponsors in the future planning, establishment of realistic mitigation requirements and protection for the desert tortoise.

Keywords: Kern River, threatened/endangered species, desert tortoise, right-of-way

INTRODUCTION

The Kern River Gas Transmission Company's (Kern River's) 2003 Expansion Project (Project) traversed approximately 320 miles of desert tortoise habitat in Utah, Nevada, and California. With the exception of an approximately 3-mile reroute in the Clark Mountains in California, the Project loops existing pipeline systems that were installed in 1991 and 1992: In desert tortoise habitat, 238 miles of the Project parallel the Kern River Pipeline System, and the westernmost 82 miles parallel the Mojave Pipeline System, which is jointly owned and operated by Mojave and Kern River. By comparing the data collected during the 1991/1992 pipeline projects and the 2003 Project, a general desert tortoise population trend can be developed. This information can be used as a tool by regulatory agencies and project sponsors for planning purposes, to develop realistic mitigation requirements, and to protect the desert tortoise.

Because of the extensive preconstruction survey work completed in conjunction with the original pipeline, Kern River assumed the presence of tortoises along the entire extent of suitable habitat in the Mojave Desert. The Biological Opinion (BO) issued by the United States Fish and Wildlife (USFWS) and the 2081 Permit issued by the California Department of Fish and Game (CDFG) outlined the specific mitigation measures that Kern River was required to implement before, during, and after construction in desert tortoise habitat. This paper only provides comparisons for the portions of the pipeline systems that were constructed by Kern River, excluding the 82 miles where the 2003 system parallels the Mojave Pipeline System. However, for the benefit of future projects that may be constructed in proximity to the parallel Mojave and

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Kern River Systems, tortoise data from construction of this section of the 2003 Expansion Project are provided.

PROJECT DESCRIPTION

Kern River 2003 Expansion Project

Construction of the Project was completed in distinct spreads, which provided the basis for comparisons of the original pipeline and the 2003 Expansion Project. In its entirety, the Project involved construction of approximately 720 miles of 36- and 42-inch-diameter pipelines from Wyoming to California, completed in 10 distinct spreads. The project also included construction of three new compressor stations, modifications to six existing compressor stations, as well as modifications to meter stations, pig launcher/receiver facilities, and mainline valves. Portions of the right-of-way (ROW) that are outside of desert tortoise habitat are not discussed in this paper. All, or portions of five construction spreads, were located in areas of desert tortoise habitat. Spread 6 included of 13.4 miles of desert tortoise habitat in Washington County, Utah. Spread 7 consisted of 84.7 miles of pipeline in desert tortoise habitat, extending from the Utah/Nevada border to the Las Vegas area. Spread 8 consisted of 54.4 miles of pipeline in desert tortoise habitat, extending from the Las Vegas area across the Nevada/California border. Spread 9 consisted of 84 miles of pipeline in desert tortoise habitat, extending to the Daggett Compressor Station near Barstow, California. Spread 10, consisted of 82.4 miles of pipeline in desert tortoise habitat, paralleling the Mojave Pipeline system from the Daggett Compressor Station into Kern County.

Except where required by topography, land use, the presence of other utilities, or other constraints, the pipeline loops were laid at a typical 25-foot offset from the existing pipe centerline utilizing a 75- to 90-foot construction ROW, with additional temporary work space, where required, for road and railway crossings, streams and washes, side hills, and other limiting features. Launcher/receiver facilities and mainline valves were constructed within the fence lines of or adjacent to other aboveground facilities to the extent feasible to minimize impacts. Construction activity was restricted to the environmentally inventoried and surveyed corridor from surveys completed in 2001 and additional surveys conducted immediately prior to construction by biological monitors and accepted as variances to the construction permit by regulatory agencies.

Desert tortoise habitat

The desert tortoise, a federally threatened and state-protected species, is known to occur throughout the Mojave Desert. Construction of the Project involved traversing approximately 320 miles of desert tortoise habitat, including over 100 miles of USFWS-designated critical habitat. This critical habitat was designated in 1994, after completion of the original pipeline system. Six distinct critical habitat units are traversed. The Beaver Dam Slope Critical Habitat Unit has components in both Utah and Nevada. The Mormon Mesa Critical Habitat Unit is located in Nevada, north and east of Las Vegas. The remaining four units (Ivanpah, Superior-Cronese, Ord-Rodman, and Fremont-Kramer) are located in California. These critical habitat designations were based on the proposed desert wildlife management areas from the 1993 USFWS Draft Recovery Plan for the Desert Tortoise (Mojave Population), which were eventually incorporated into the final Recovery Plan (FWS, 1994a). Expected population levels within the critical habitat units are discussed in the Proposed Desert Wildlife Management Areas companion document to the Recovery Plan (FWS, 1994b). Critical habitat designations generally incorporated areas previously classified as Bureau of Land Management (BLM) Category 1 and 2 tortoise habitat. Critical habitat lands require greater habitat mitigation offset per the methodologies outlined in the Compensation for the Desert Tortoise (Desert Tortoise Compensation Team, 1991). BLM Category 3 lands, as well as Category 1 and 2 lands excluded from critical habitat, are now simply designated as non-critical habitat with a typical mitigation offset ratio of 1:1. Figures 1 and 2 indicate the locations of the 1991 and 2003 construction spreads in relation to critical desert tortoise habitat.

METHODOLOGY

All construction activities associated with the 2003 Expansion Project were completed under the terms and conditions identified in the USFWS BO (File No. 1-5-02-F-476) issued for the project on July 9, 2002. The CDFG issued an Incidental Take Permit (No. 2081-2002-005-06) for the project on October 28, 2002. An approved Lead Biologist was designated for each construction spread, responsible for the implementation of all permit conditions. Tortoise monitors supported the Lead Biologist, with the number of support personnel based on the specific construction activities occurring. During the Project, these biologists maintained a record of all sensitive species encountered during surveying and monitoring.

All construction activity was preceded by a pre-construction survey of the area to be disturbed and a 50-foot buffer outside of the ROW and extra workspace. The surveys were done on a continuing basis, one to two weeks prior to ground disturbance, and were intended to locate desert tortoises, burrowing owls, and other sensitive plant and animal species. The surveys were performed by authorized biologists and tortoise handlers using survey techniques that provided 100% coverage to the area surveyed. All burrows within the designated work area that could have harbored

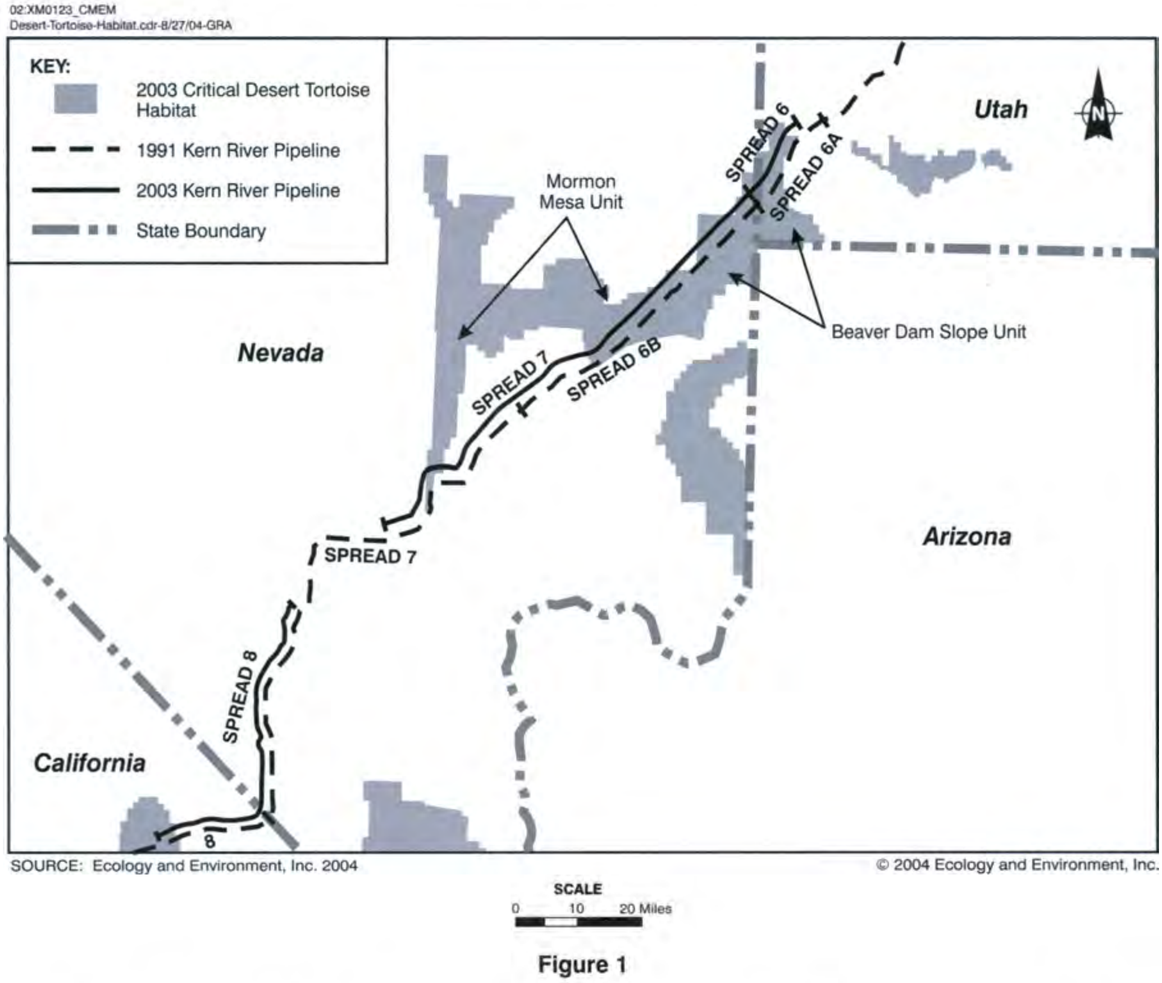

Fig. 1. Location of Kern River mainline and 2003 expansion project ROWs with respect to desert tortoise habitat in Utah and Nevada.

a tortoise were excavated and collapsed. All burrows within the 50-foot buffer area outside the designated work area that could have contained a tortoise were inspected for tortoises and their signs and flagged with green and white striped flagging. All data regarding these burrows and tortoises were compiled and submitted to the resource agencies in post-construction monitoring reports.

All construction activities were performed under the supervision of biological monitors. These monitors arrived on the job site ahead of the construction crews, clearing the access roads on the way in, and checked the area under and around all the construction equipment before it was allowed to operate. The monitors surveyed the area around and in front of the equipment in the direction the equipment was working, and checked all open excavations three or more times per day. The monitors also led the construction crews out at the end of the workday, to clear the access road. Several monitors were tasked with "roving," or driving the access roads to clear them of desert tortoises in front of any vehicular traffic. These monitors also were available in the event of a construction crew splitting into two crews and requiring another monitor. Because of the sheer volume of construction equipment and their distribution along the length of the ROW, Kern River was required at times to have as many as 45 tortoise monitors present on a spread to provide the coverage required by the permitting agencies.

Similar permit conditions were issued as part of the BO for the original pipeline construction, indicating that similar monitoring had been required. When the numbers of monitors were compared, the 2003 Expansion Project, had, in fact, greater monitoring levels than the original construction program, even though the 2003 Expansion Project was largely constructed during the tortoise's inactive season. However, the numbers of monitors cannot be directly compared since no information was available regarding the size and distribution of equipment and work crews for the original construction effort. In addition, to maintain or expedite construction progress for the 2003 Expansion Project, Kern River's construction contractors mobilized additional equipment and work crews, requiring higher numbers of monitors, but for a shorter duration. Data from the original construction effort was obtained from the-post construction monitoring reports prepared by Kern River and submitted to the resource agencies.

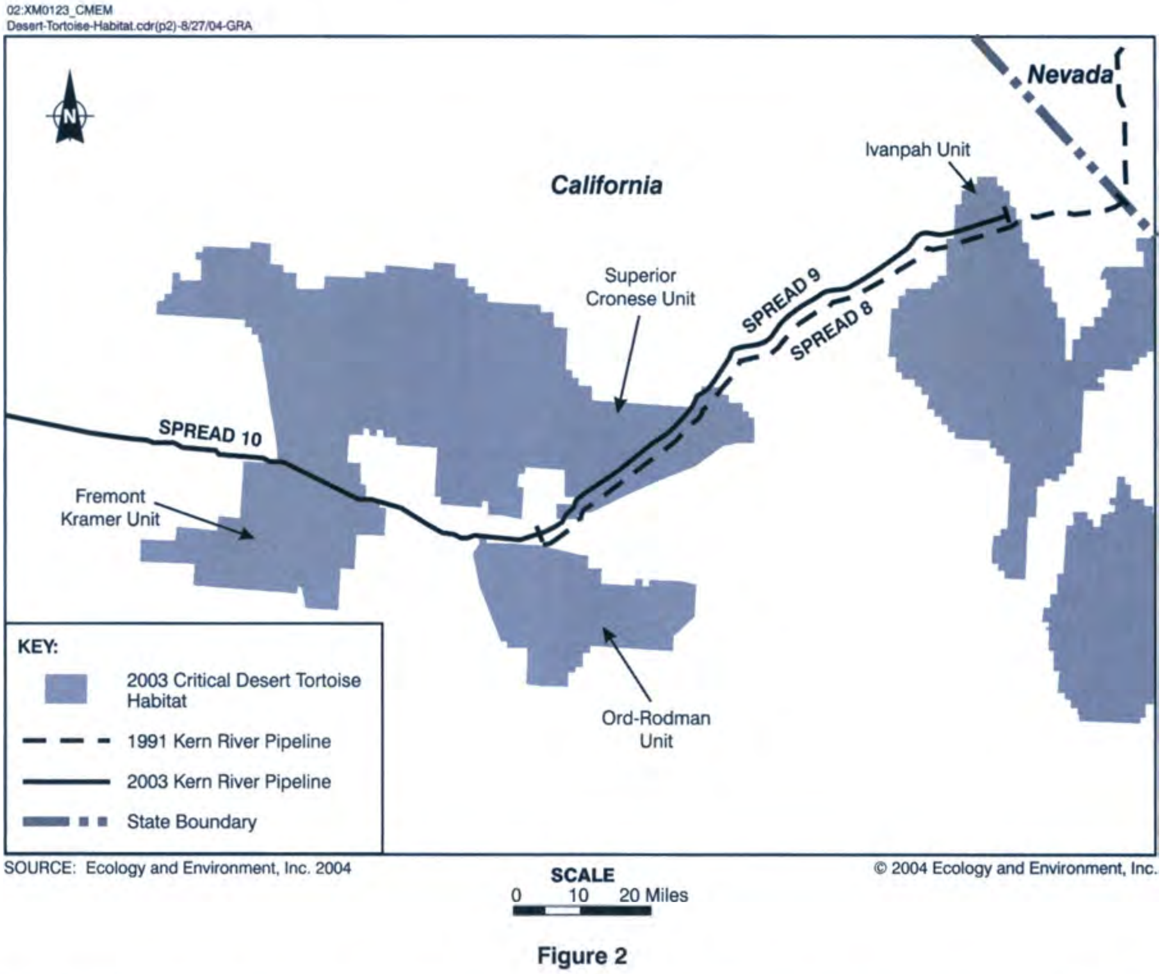

Fig. 2. Location of Kern River mainline and 2003 expansion project ROWs with respect to desert tortoise habitat in California.

Table 1. Comparison of desert tortoise data along the Kern River pipeline ROW for the original and 2003 expansion projects

State	Pipeline segment	1991 Construction			2003 Expansion		
		Tortoises	Relocations	Excavations	Tortoises	Relocations	Excavations
Utah		70	8	68	2	0	7
Nevada							
	Subsection A	106	33	335	53	15	17
	SubSection B	42*	14	44*	57	19	28
	SubSection C	500*	168	530*	246	76	224
California							
	SubSection A	705	107	692	195	95	305
	Subsection B	N/A	N/A	N/A	301**	25	647

*Site Specific data not provided in available reports. Numbers estimated based on the distribution of relocated tortoises.
**Due to poaching concerns, burrows were not flagged after mid-February to avoid disturbance. This impacted the ability to track individual tortoises, resulting in an underestimation of tortoise numbers.

RESULTS AND DISCUSSION

Construction spreads for the two projects did not overlap exactly, requiring interpretation of the data to provide comparisons. Data from the original pipeline construction projects were obtained from the project compliance monitoring reports prepared for Kern River. Data for the 2003 Expansion Project were obtained from the project summary reports prepared for Kern River and, where necessary, the raw field data archived for the Project. Table 1 provides a comparison of the two construction seasons for specific pipeline segments.

The Utah portion of the 1991 Kern River ROW within areas of identified desert tortoise habitat, consisting of 17 miles of ROW, was constructed as

Spread 6A. During construction of the 2003 Expansion Project, only 13 miles of pipeline ROW in Utah was within areas considered to be desert tortoise habitat, encompassing the Beaver Dam Slope Critical Habitat Unit. Based on consultation with agency representatives, the extent of desert tortoise habitat for the 2003 Expansion Project was defined by the transition from a Mojave Desert scrub ecosystem to a pinyon-juniper ecosystem. During the original installation, defined habitat extended into the pinyon-juniper ecosystem.

For the purposes of this comparison analysis, Nevada was divided into three subsections. Subsection A consists of the first 52.7 miles of the Nevada ROW encompassing all of the 1991 Spread 6B and a portion of the 2003 Spread 7. Both the Beaver Dam Slope and Mormon Mesa Critical Habitat Units are traversed in this subsection. Subsection B consists of the first portion of the 1991 Spread 7 and the remaining 33 miles of the 2003 Spread 7. This subsection traverses no critical desert tortoise habitat, although the route does parallel approximately 3 miles of critical habitat. Subsection C, which consists of approximately 36 miles of ROW, is defined by Spread 8 of the 2003 Expansion Project from Las Vegas to the California border, which includes a portion of the 1991 Spread 7. This area includes the Large Scale Translocation Site (LSTS), which has been established to provide habitat for tortoises relocated out of Las Vegas due to the large amount of development occurring in that area. The skipped portion around Las Vegas is not discussed due to urban development, which has significantly altered the ecosystem's suitability for desert tortoise. Because the Nevada spreads were offset between the two years of construction, available data for the 1991 construction season provides only locational data for the relocated tortoises. Therefore, the locational data for burrows and other tortoises observed, but not harassed, were estimated for Spread 7 of the 1991 construction project.

For discussion purposes, California was divided into two subsections. Subsection A encompasses the ROW from the Nevada/California line to Daggett. In 1991, construction of this section was completed as Spread 8. For the 2003 Expansion project, the first 5 miles of section were completed as part of Spread 8, with the remaining 85 miles completed as Spread 9. Subsection B encompasses Spread 10 of the 2003 Expansion Project, which extended from Daggett, approximately 82 miles along the Mojave Pipeline System. No comparison has been provided for Subsection B due to lack of monitoring data from the 1991 construction effort.

Utah

Utah desert tortoise populations demonstrated the most significant variation between the 1991 and 2003 construction seasons. One of the two tortoises identified on Spread 6 during 2002 was actually found several miles from the ROW during the survey of a drainage receiving hydrostatic test water discharge. Therefore, only a single tortoise was actually found in proximity to the project area. While neither tortoise exhibited signs of Upper Respiratory Tract Disease (URTD), the lack of tortoises would seem to indicate a precipitous drop in population levels in the intervening years between construction of the original pipeline and the 2003 Expansion Project. No significant signs of predation were evident that might explain the population decrease.

Granted that construction of the 2003 Expansion Project occurred from October through February, during the period of reduced tortoise activity, if a healthy population still existed, we would expect to find significantly more than a single tortoise in proximity to the Project. Most of the habitat traversed in Utah is classified as part of the Beaver Dam Slope Critical Habitat Unit, with the vegetation consisting primarily of Mojave creosote bush scrub interspersed with Joshua trees and other succulents. No apparent disturbances were evident outside the established utility corridor utilized for the project that would account for the population drop.

Nevada

The Beaver Dam Slope and Mormon Mesa Critical Habitat Units are traversed by Subsection A. While comprising the greatest mileage of pipeline ROW, this portion of the project area had the lowest density of tortoises seen in Nevada. Of the 53 tortoises identified during the recent construction activity, it is estimated that 21 of the tortoises were physically identified within these critical habitat units, which are traversed for 26.8 miles. Tortoise findings were largely scattered throughout the remainder of the section, with the exception of approximately 10 tortoises found over a relatively short distance in the Glendale area. Nearly half of the tortoises were found on access roads leading to the construction area. Of interest is that, of the tortoises found in this section during the 2003 Expansion Project, only five tortoises were identified during the months of November through February; the majority of tortoises were seen in March and April, only after tortoise activity had increased. Based on the comparisons of data between the two construction seasons, the desert population would appear to be in decline in this portion of the project area.

Although Subsection B traversed no critical habitat units, the route does parallel a portion of the Coyote Springs Critical Habitat Unit for approximately 3 miles. The vast majority of the desert tortoises seen on this spread were located within 5 miles of the Coyote Springs Critical Habitat Unit. Although the seasonal differences between the original project and the 2003 Expansion Project prevent direct correlation, it appears that tortoise numbers have, at a minimum, remained constant throughout this area and potentially increased. This is critical to note, given the energy development (i.e., power plants and infrastructure) that is occurring in the Dry Lake area of Clark County. Based on a comparison of the two data sets, tortoise population levels seem to be stable north and east of Las Vegas, even with the increasing encroachment of development.

Subsection C of the ROW south and west of Las Vegas, extending to the California state line, had by far the greatest density of desert tortoise. The vast majority of tortoise sitings occurred in April and May, when more tortoise activity would be anticipated. During the construction season for the 2003 Expansion Project, only 28 tortoises were observed between November and February, all but one being found in burrows. It should be noted that 66 carcasses were found during the course of construction, indicating a potentially higher tortoise mortality rate. Approximately 70 tortoises were observed in the first 5 miles of this section, indicating a significant tortoise population. The other area on Spread 8 with an extremely high tortoise density was the LSTS, which the Kern River ROW traverses for approximately 9.6 miles. A total of 107 tortoises were observed within the LSTS. An additional 36 tortoises were observed within 2 miles north and south of the LSTS. Since the LSTS is fenced and managed as a relocation site (i.e., no anticipated development), it can be expected that populations will remain high, unless disease (e.g., URTD) decimates the population.

Only a few tortoises in Nevada were identified (positively or suspected) as having URTD. In all instances, these individuals exhibited atypical behavior. These individuals were active during cooler periods when tortoises would not normally be expected to forage or show any movement.

Because the 1991 construction project occurred primarily during the more active tortoise season, and only the last few months of the 2003 Expansion Project coincided with the more active season, it is not possible to draw any direct correlations between the numbers of tortoises seen. However, the number of carcasses found seems to indicate an elevated level of mortality. Given the numbers of tortoises that have been relocated to the LSTS, this is not surprising.

California

Two critical habitat units are traversed by Subsection A. The Ivanpah Critical Habitat Unit overlaps with the last 3.3 miles of Spread 8 of the 2003 Expansion Project, and the first 8.2 miles of Spread 9. Within the Spread 8 portion of the Project, of the 45 tortoises identified in California, 23 were located either within the Ivanpah Critical Habitat Unit or within 2 miles of the unit, indicating a high density of tortoises. Only four of these tortoises were found in burrows during the preconstruction surveys, with the remainder found foraging during the more active season. Conversely, only five tortoises were found in the first 8.2 miles of Spread 9, only two of which were found in burrows. Although this segment of Spread 9 would have largely been constructed in the inactive season, a primary access road paralleled this portion of the ROW, and tortoise monitors were present throughout construction. It is expected that a higher tortoise density would have been evidenced by more incidental sitings by these monitors throughout construction. Based on the monitoring reports, only seven tortoises within the Ivanpah Critical Habitat Unit required relocation on Spreads 8 and 9. No tortoises within this section exhibited signs of URTD.

Based on data from the original pipeline construction project, 18 tortoises were relocated within the Ivanpah Critical Habitat Unit and an estimated 100 tortoises were identified. This would seem to indicate that the tortoise population has decreased significantly in the 11 years between construction projects.

The results for the Superior-Cronese Critical Habitat Unit reflect a similar decrease in tortoise numbers. Construction monitoring in 2003 identified 30 tortoises within this unit, while data for the 1991 project indicate an estimated 290 tortoises, based on the relocation of 44 tortoises.

Although not specifically mapped as critical habitat units, areas of more concentrated desert tortoise populations were also evident on Spread 9. High numbers of tortoises were identified in the central portion of the spread between the mapped South Avawatz and Soda Mountain Wilderness Study Areas. More than 50 tortoises were concentrated over an approximately 20-mile segment of the pipeline. These numbers more closely approximate the data from the original construction effort, during which an estimated 65 to 70 tortoises were identified. This is one of the more remote sections of the pipeline ROW and may experience lower human activity.

Data for Subsection B is provided for informational purposes only, since no detailed comparative data were available from the construction of the original line. Spread 10 had by far the greatest tortoise densities seen along the Kern River ROW. A total of 301 tortoises were identified during monitoring activities. Unusually warm winter conditions resulted in tortoise activity throughout the construction phase.

The actual number of tortoises was likely higher, but due to concerns regarding poaching and/or disturbance of individuals, monitors discontinued marking burrows and removed all flagging from the ROW in late February, thus preventing an accurate accounting of tortoises. Therefore, the discussions regarding Spread 10 provide a good estimate of tortoise distribution, but not the actual numbers encountered. Approximately 20 individuals on Spread 10 were identified as having URTD, and several individuals were submitted to Dr. Kristen Berry for necropsy. The presence of URTD in such a high-density population could have far reaching ramifications for the population, which should be monitored.

Two small portions of the Ord-Rodman Critical Habitat Unit, totaling 1.7 miles, are traversed in the first 14 miles of this segment. Because of the high density of tortoises, monitoring efforts were actually extended away from the pipeline ROW to a greater distance than required to better understand the resource and ensure adequate monitoring levels. Over 125 tortoises were identified in burrows within approximately 500 feet of the construction ROW in this area, with the total number of tortoises observed exceeding 200.

The second critical habitat unit, the Fremont–Kramer, is located in the central portion of this segment and is traversed for 15.3 miles. Based on the monitoring data, nearly 50 tortoises were located in burrows in proximity to the ROW, again indicating a high density of tortoises. In comparison, only five tortoises were identified in the last 37 miles of ROW on Spread 10.

CONCLUSIONS

This paper evaluated population trends of the desert tortoise along 238 miles of pipeline ROW through the Mojave Desert in Utah, Nevada, and California. Kern River currently operates two pipelines in this ROW, the first constructed in 1991, and the second recently constructed in 2002 and 2003. Based on comparisons of monitoring data collected during each of the construction efforts, general trends can be identified. The desert tortoise population has apparently declined in the Beaver Dam Slope and Mormon Mesa Critical Habitat Units in Utah and Nevada in proximity to the Kern River Pipeline System. Population levels in the LSTS and the non-critical habitat areas in Nevada appear to be stable.

In California, tortoise populations appear to have decreased in the Ivanpah and Superior-Cronese Critical Habitat Units, while maintaining stable levels in between these units. The Ord-Rodman and Fremont-Kramer Critical Habitat Units appear to support the greatest density of tortoises along the Kern River ROW. However, the presence of high numbers of URTD-positive individuals in California is alarming due to the high density of tortoises and the likely interaction of infected individuals with uninfected individuals.

The general lack of movement of desert tortoise confirms the value of construction timing during the cooler winter months. Tortoises that showed signs of activity during this period were suspected of having URTD. The appearance of tortoises during the colder periods generally corresponded to precipitation/rain events that left puddles in the desert. For the most part, little tortoise activity was noted until warmer temperatures were maintained and the lush annual growth of the desert began to emerge. Where normal weather conditions were present, from Utah down toward Barstow, California, tortoise sitings during the colder season from November through February were limited to animals in burrows on or adjacent to the ROW. Not until the temperature regime modified did any significant tortoise movement occur.

This paper has made no attempt to compare population numbers to expected levels as presented in the Recovery Plan (FWS, 1994a); rather, it has attempted to present apparent population trends based on two distinct monitoring efforts associated with construction along the Kern River ROW. It should be noted that while collocated with sections of power lines, the original Kern River 1991 project established new pipeline ROW, whereas the 2003 Expansion Project generally paralleled and overlapped existing ROW and previously disturbed areas. While desert tortoise were identified throughout the entire Mojave Desert, it seems apparent the population levels are declining, and, in some instances, have been reduced to levels that are likely not sustainable. The monitoring conducted for the 2003 Expansion Project confirmed that little tortoise activity is present during the cooler winter periods. It is hoped by the authors that the data presented in this paper can be used in future energy development projects in the Mojave Desert to allow for more site-specific monitoring requirements versus a carte blanche application of mitigation requirements.

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REFERENCES

Desert Tortoise Compensation Team. 1991. Compensation for the Desert Tortoise. A Report Prepared for the Desert Tortoise Management Oversight Group.

Fish and Wildlife Service. 1994a. Desert tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland Oregon.

Fish and Wildlife Service. 1994b. Proposed Desert Wildlife Management Areas for Recovery of the Mojave population of the desert tortoise. U.S. Fish and Wildlife Service, Portland Oregon.

Kern River Gas Transmission Company. 2003a. Kern River 2003 Expansion Project, Project Summary Report Spread 6. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003b. Kern River 2003 Expansion Project, Project Summary Report Spread 7. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003c. Kern River 2003 Expansion Project, Project Summary Report Spread 8. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003d. Kern River 2003 Expansion Project, Project Summary Report Spread 9. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003e. Kern River 2003 Expansion Project, Project Summary Report Spread 10. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2001. Desert Tortoise Assessment. Mojave Desert Tortoise Population. Utah, Nevada, and California. Kern River 2003 Expansion Project. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 1992a. Kern River pipeline Compliance Monitoring Report Biological Resources, Utah Portion-Spread 6A, Desert Tortoise Habitat. Prepared by Dames and Moore.

Kern River Gas Transmission Company. 1992b. Kern River pipeline Compliance Monitoring Report Biological Resources, Nevada Portions Spreads 6B and 7. Prepared by Dames and Moore.

Kern River Gas Transmission Company. 1992c. Kern River pipeline Compliance Monitoring Report Biological Resources, California Portion Spread 8. Prepared by Dames and Moore.

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Desert Tortoise Mitigation: Lessons Learned a Case Study of the Kern River 2003 Expansion Project

Mike Donnelly, Brent Arnold, Tim Powell, and Dave Schultz

In the fall, winter, and spring of 2002 and 2003, the Kern River Gas Transmission Company (Kern River) constructed the approximate 720-mile 2003 Kern River Expansion Project Pipeline from Wyoming, through Utah and Nevada, to California. Approximately 320 miles of Desert Tortoise habitat was traversed by the project, including over 100 miles of United States Fish and Wildlife Service (USFWS) designated critical habitat. To avoid and minimize impacts to the Desert Tortoise, a federally-threatened and state-protected species, Kern River implemented a comprehensive biological monitoring plan during construction and provided monetary compensation for impacts to desert tortoise habitat. The biological monitoring plan included on-site monitoring on all construction activities within tortoise habitat as well as the implementation of project-wide conditions (i.e. speed limits, and equipment checks). During peak construction, approximately 160 monitors were utilized on four active spreads within the Mojave Desert. During construction, 851 tortoises were found in the project vicinity. It was determined that only one tortoise was killed by construction or construction related activities. While the mitigation measures employed were adequate to minimize project-related takes and impacts to sensitive species and their habitats, some of the measures could have been reduced to provide significant cost savings without increasing the risk to the species. Measures that could have been modified realistically included: reduced monitoring during periods of low tortoise activity, primarily in the winter inactive months; reduced monitoring in areas with low concentrations of tortoises; and modification of reduced speed limits on access roads and along the ROW during the inactive season.

Keywords: Kern River, threatened/endangered species, compliance monitoring, biological monitoring, mitigation costs, biological consultation, right-of-way

INTRODUCTION

The Kern River 2003 Expansion Project was the first major natural gas project recently approved and constructed under the developing Federal Energy Regulatory Commission (FERC) 7(c) pre-filing certification and permitting process. In order to facilitate the expedited approval of the Project to meet a May 2003 In-Service date, Williams Gas Pipeline (WGP) and Kern River Gas Transmission Company (Kern River) entered into pre-filing consultation with numerous federal and state agencies on issues that included desert tortoise protective measures and mitigation needs, and restoration of the right-of-way (ROW) to pre-construction conditions. Where the ROW crossed desert tortoise critical habitat, WGP and Kern River designed and implemented an extensive set of mitigation measures to offset any potential impacts to this species.

Because of the extensive preconstruction survey work completed in conjunction with the original pipeline (1991), Kern River assumed the presence of tortoise along the entire extent of suitable habitat in the Mojave Desert. The Biological Opinion (BO) issued by the United States Fish and Wildlife Service (USFWS) was also used by the California Department of Fish and Game (CDFG) to support issuance of a 2081 Permit. Differences in USFWS objectives between of-

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fices in Utah, Nevada and California, the role of the U.S. Bureau of Land Management in desert tortoise preservation, CDFG requirements and objectives, and participation by desert tortoise interest groups complicated the negotiation of mutually agreeable protection measures. Due to Kern River's contractual obligation to meet a pre-determined in-service date, Kern River agreed to a set of proposed mitigation measures that satisfied the various agencies while including a condition that allowed Kern River flexibility and an opportunity to pursue modifications to BO conditions during construction, should one or more prove unnecessary. The FERC and California State Lands Commission (CLSC), under the Third-Party Compliance Program, monitored compliance during pipeline construction.

Based on data collected during the course of construction, it became evident that the built-in flexibility was difficult to implement given the various interests and differences in the interpretation and application of the established mitigation monitoring requirements. As a result, Kern River was unable to take full advantage of appropriate modifications to construction requirements based on species presence, weather conditions, and other factors that were intended to focus monitoring efforts on the resource. By applying the lessons learned during the Kern River 2003 Expansion Project, environmental costs could be reduced while maintaining an adequate level of protection for the desert tortoise.

PROJECT DESCRIPTION

Kern River 2003 Expansion Project

Construction of the Kern River Project was completed in 10 distinct spreads to facilitate construction. The Project, in its entirety, consisted of the construction of approximately 720 miles of 36- and 42-inch diameter pipeline from Wyoming to California. The project also included construction of three new compressor stations, modifications to six existing compressor stations, and modifications to meter stations, pig launcher/receiver facilities, and mainline valves. Portions of the ROW falling outside the desert tortoise habitat are not discussed in this paper. All or portions of five construction spreads were located in desert tortoise habitat: Spread 6 included 13.4 miles of desert tortoise habitat in Washington County, Utah. Spread 7 consisted of 84.7 miles of pipeline in desert tortoise habitat, extending from the Utah/Nevada border to the Las Vegas area. Spread 8 consisted of 54.4 miles of pipeline in desert tortoise habitat, extending from the Las Vegas area across the Nevada/California state border. Spread 9 consisted of 84 miles of pipeline in desert tortoise habitat, extending to the Daggett Compressor Station near Barstow, California. Spread 10 consisted of 82.4 miles of pipeline in desert tortoise habitat, paralleling the Mojave Pipeline system from the Daggett Compressor Station into Kern County. Figure 1 shows the spread locations in relation to desert tortoise habitat.

Except where required by topography, land use, presence of other utilities, or other constraints, the pipeline loops were laid at a typical 25-foot offset from the existing pipe centerline utilizing a 75- to 90-foot construction ROW with additional temporary work space, where required, for road and railway crossings, streams and washes, side hills, and other limiting features. Launcher/receiver facilities and mainline valves were constructed within the fence lines of or adjacent to other aboveground facilities to the extent feasible to minimize impacts. Construction activity was restricted to the environmentally inventoried and surveyed corridor from surveys completed in 2001, spring 2002, and additional surveys conducted immediately prior to construction in fall 2002 by biological monitors to support variances to the construction permit by regulatory agencies to allow for changes in temporary workspace or access road modifications.

Desert Tortoise habitat

The desert tortoise is a federally listed threatened and state-protected species, known to occur throughout the Mojave Desert. Construction of the Project involved traversing approximately 320 miles of Desert Tortoise habitat, including more than 100 miles of USFWS-designated critical habitat. The Beaver Dam Slope unit has components in both Utah and Nevada. The Mormon Mesa Unit is located in Nevada, north and east of Las Vegas. The remaining four units (Ivanpah, Superior-Cronese, Ord-Rodman, and Fremont Kramer) are located in California. These critical habitat designations were based on the proposed desert wildlife management areas from the 1993 USFWS Draft Recovery Plan for the Desert Tortoise (Mojave Population), which were eventually incorporated into the final recovery plan (FWS, 1994a). Expected population levels within the critical habitat units are discussed in the Proposed Desert Wildlife Management Areas companion document to the Recovery Plan (FWS, 1994b). Critical habitat lands require greater habitat mitigation offset per methodologies outlined in the *Compensation for the Desert Tortoise* (Desert Tortoise Compensation Team, 1991). The critical habitat units traversed are also identified on Fig. 1.

REGULATORY CONTEXT

Overall, the Kern River 2003 Expansion Project fell under the jurisdiction of, and was certificated by, the FERC under Section 7(c) of the U.S. Natural Gas Act of 1938. As lead federal agency, the FERC also was responsible for National Environmental Policy Act (NEPA) review and compliance review. In addition,

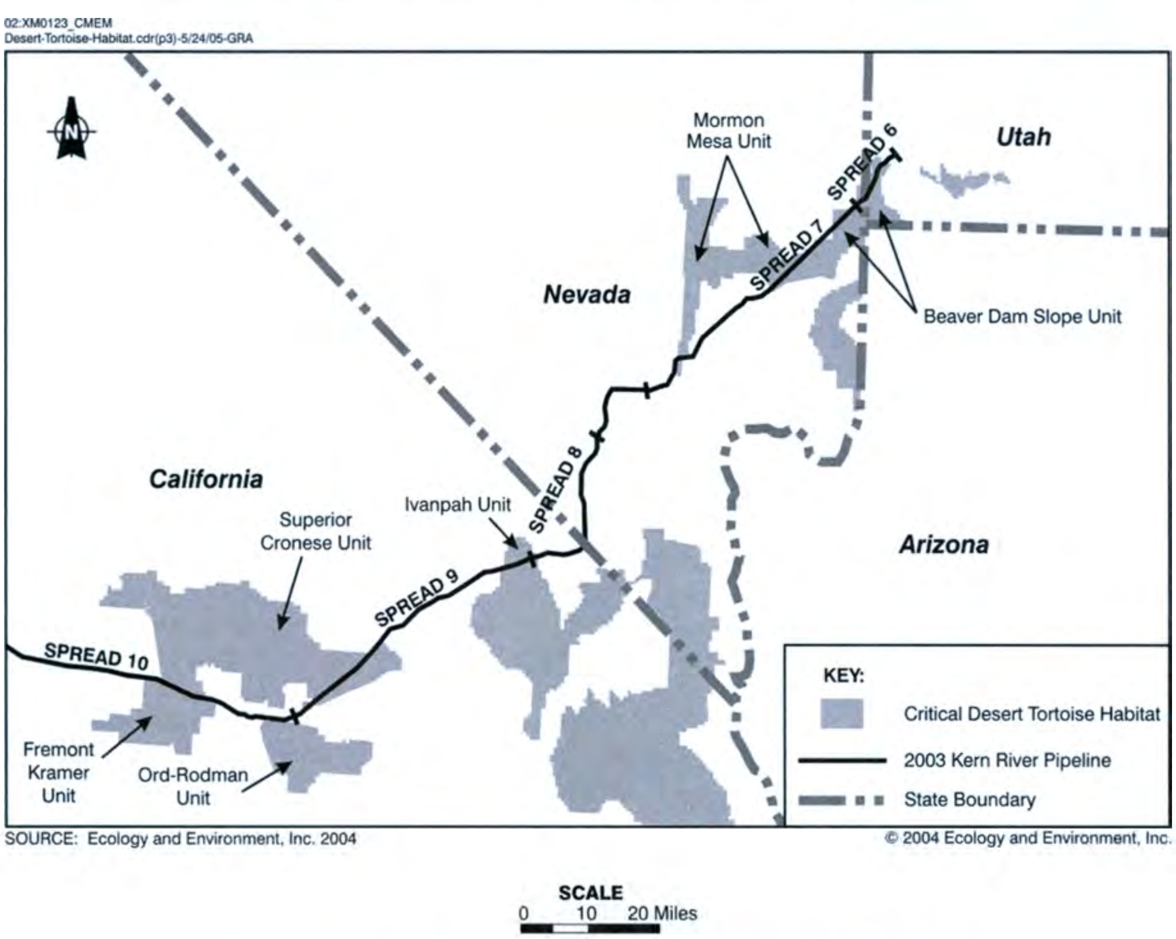

Fig. 1. Location of Kern River 2003 expansion project within the Mojave Desert.

about 50 percent of the lands crossed were federal lands predominantly managed by the U.S. Department of the Interior, Bureau of Land Management (BLM). The BLM was the lead federal agency for amending the Grant of Right-of-Way under Section 28 of the Mineral Leasing Act, had collective NEPA review responsibility for all federal lands, was a cooperative agency with the FERC, and coordinated with the other federal land management agencies. With respect to NEPA compliance under the Endangered Species Act (ESA), FERC relied heavily on the input from the USFWS, whose involvement is detailed below.

In addition to the federal statutes, the CSLC also had comprehensive review responsibility under the California Environmental Quality Act (CEQA) and became a cooperative agency with the FERC and BLM for the Environmental Impact Statement/Environmental Impact Report (EIS/EIR), which was subsequently issued as final in June 2002 (FERC et al., 2002c). Just as FERC was required to address the ESA in its NEPA analysis, the CSLC was required to address the California ESA (CESA) as part of its CEQA analysis. The CESA prohibits the take of any species of wildlife that is included in the list of endangered species, the list of threatened species, or the list of candidate species. The CDFG, however, may authorize, by permit, the take of such species if the conditions set forth in Section 2081(b) and Section 2081(c) are met.

USFWS issuance of the biological opinion

The BO serves as the primary vehicle for the protection of the desert tortoise under the ESA and provides substantiation as to whether the USFWS believes a project will adversely affect federally listed or proposed species or their habitat. Kern River initiated informal consultation for the Project in early 2001 in conjunction with the field surveys completed for the 2003 Expansion Project and coordinated with the USFWS extensively throughout the project. Although three USFWS offices were involved (Salt Lake City, Las Vegas, and Barstow), the Las Vegas Office was established as the lead for this project. The USFWS consulted with the BLM and Utah, Nevada, and California state agencies in their review and approval of the Project.

A *Desert Tortoise Assessment* was prepared by Kern River and submitted to FERC, as part of the August 2001 FERC filing. This assessment outlined the conservation measures that Kern River proposed to implement to reduce the magnitude of the impacts to desert tortoise. The proposed conservation measures were based on construction during periods of high desert tortoise activity. Kern River noted that since construction was to occur in the hibernation/ estivation period, all the measures might not be necessary or applicable. Kern River proposed to coordinate with the USFWS, BLM, and state resource agencies to determine specific timing and implementation of the proposed measures. In addition to the conservation measures, Kern River also presented a habitat conservation approach through land acquisition or financial remuneration. Kern River suggested a reduced mitigation ratio for those portions of the pipeline that had been previously mitigated in conjunction with the original Kern River pipeline constructed in 1991. Based on agency unwillingness to negotiate mitigation ratios, Kern River modified their proposal to reflect compensation as outlined by the Desert Tortoise Compensation team (1991). Disturbance in critical habitat was mitigated on 3:1 and 5:1 ratios, dependent on whether prior disturbance existed, and all non-critical habitat was mitigated at a ratio of 1:1.

In February 2002, the FERC requested formal consultation on the desert tortoise. In the Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR) for the Project, FERC indicated that the Kern River 2003 Expansion Project *was likely to adversely affect* the desert tortoise and its designated critical habitat. The DEIS/EIR concluded though, that the proposed action as described, "... would not, however, make any irreversible or irretrievable commitments of resources that would foreclose formulation or implementation of any reasonable or prudent alternative needs to avoid jeopardizing the continued existence of the species and adverse modification to its critical habitat."

The BO for the 2003 Expansion Project was issued to the FERC, by the USFWS, on July 9, 2002. The USFWS concluded in the BO that the "... action, as proposed is not likely to jeopardize the continued existence of the desert tortoise... and is not likely to destroy or adversely modify designated critical habitat for the desert tortoise to the extent that it no longer serves as recovery areas." The BO also provided Kern River with an Incidental Take Statement under Section 9 of the ESA outlining a reasonable level of anticipated take or harassment, based on implementation of the stated terms and conditions.

This conclusion was based on the Project design, the specific conservation and reclamation measures proposed by Kern River, the anticipated desert tortoise densities, and the fraction of impacts size in the context of the extent of critical habitat in the Mojave Desert. With the BO, the USFWS identified reasonable and prudent measures that were necessary and appropriate to minimize the take of desert tortoise. Primarily, FERC was required to "implement measures to minimize mortality or injury of the desert tortoise due to construction activities, including blasting and use of heavy equipment." In order to be exempt from Section 9 of the ESA, FERC and Kern River were required to comply with numerous terms and conditions to implement previously identified reasonable and prudent measures. The terms and conditions largely mirrored Kern River's proposed Conservation Measures designed to protect the tortoise. Several conditions, however, were changed slightly, which directly affected the scope of Kern River's monitoring efforts and provide the focus of this paper. Specifically, the following conditions were issued as part of the BO:

1: To implement Reasonable and Prudent Measure Number 1, FERC and KRGT shall fully implement the following measures:
   a) ...FERC and KRGT shall provide a minimum of one Field Contact Representative (FCR) for each contiguous stretch of construction activity. The FCR's will be responsible for overseeing compliance with protective stipulations for listed species. BLM and the Service shall approve the FCRs.
   d) ...Except on county-maintained roads, vehicle and equipment speed limits shall not exceed 20 MPH within suitable desert tortoise habitat.
   f) ...FERC and KRGT shall ensure that an authorized biologist shall be assigned to each piece/ group of large equipment.
   u) During the winter, KRGT may request modification of the numbers of monitors present or other conditions developed primarily to minimize effects to desert tortoise during periods of tortoise activity. In such cases, the authorized biologist must confirm that no desert tortoise are above ground or present within the construction zone, or anticipated to be active for a minimum of three days. Any modifications would require concurrence form the FERC, and jurisdictional offices of the Service and BLM, and CDFG.

CDFG – issuance of the 2081 permit

The 2081 Permit serves as the primary vehicle for the protection of the desert tortoise under the CESA, with the CDFG acting as the responsible agency for purposes of issuing an incidental take permit where another public agency must approve the project or activity for which the permit is requested and the other agency has taken the lead agency role for purposes of compliance with CEQA. Kern River initiated consultation for the Project in early 2001 in conjunction with the field surveys completed for the 2003 Expansion Project and coordinated primarily with the CDFG Palmdale office.

Unlike the BO, the primary function of the 2081 Permit is to permit the incidental take of a state-protected species. CDFG issued the 2081 Incidental Take Permit for the Project on October 28, 2002. Furthermore, the CDFG entered into a Memorandum of Understanding (MOU) with the Lead Biologists for spreads 8, 9, and 10 (and subsequently amended as necessary), identifying individuals qualified to handle and monitor tortoises during the course of construction. Similar to the terms and conditions of the BO, the 2081 Permit was appended with a Mitigation Monitoring and Reporting Program, which outlined the specific conservation measures required in conjunction with the Project.

MITIGATION MEASURES

To avoid and minimize impacts to the desert tortoise, Kern River implemented a comprehensive biological monitoring plan during construction and provided monetary compensation for impacts to desert tortoise habitat. The plan was largely designed to assure adherence to the terms and conditions set forth in the BO and 2081 Permit. In addition to the general biological monitoring and environmental inspection conducted by Kern River, the FERC/CSLC and BLM both provided additional construction monitors to verify Kern River's compliance with the terms and conditions of all environmental permits issued for the Project.

Biological monitoring plan

Kern River's biological monitoring plan included onsite monitoring on all construction activities within tortoise habitat and the implementation of Project-wide conditions (i.e., speed limits and equipment checks). Lead Biologists were identified for each of the five spreads constructed in desert tortoise habitat and were approved by the USFWS, BLM, and CDFG. Supporting the lead biologist were any number of desert tortoise monitors who were responsible for assuring that construction activities adhered to the terms and conditions of the permits. Three levels of monitors, based on experience, were established. Authorized biologists with significant desert tortoise experience were approved to handle/relocate tortoises. Approved biologists had sufficient prior construction oversight experience to monitor equipment individually, and trainees were individuals with sufficient educational background, but little prior construction experience. These trainees were required to work closely with other approved or authorized biologists. Typically, the regulatory agencies require approved or authorized biologists to provide the majority of the monitoring. Due to the sheer numbers of monitors needed, coupled with the timeframes required for agencies to review and approve monitors, Kern River necessarily had to use trainees to prevent unnecessary construction delays due to lack of monitoring, under the supervision of approved biologists. During peak construction, approximately 160 monitors were used on four active spreads within the Mojave Desert.

All construction activity was preceded by a preconstruction survey of the area to be disturbed as well as a 50-foot buffer outside of the ROW and extra workspace. This survey was done on a continual basis, one to two weeks before ground disturbance and was done by authorized biologists and tortoise handlers using survey techniques that provided 100% coverage of the area surveyed. Tortoises located on the ROW in burrows were relocated prior to construction activities. All burrows within the designated work area, which could have harbored a tortoise, were excavated and collapsed. Desert tortoise burrows were excavated following "Guidelines for Handling Desert Tortoises During Construction Project" prepared by The Desert Tortoise Council. All burrows that could have contained a tortoise within the 50-foot buffer area outside the designated work area were inspected for tortoises and sign and were flagged with green- and white-striped flagging. During the tortoise inactive period, burrows near the ROW were enclosed with fencing to further protect the individuals. These burrows were checked for activity on a regular basis.

All construction activities were performed under the supervision of biological monitors. These monitors arrived on the job site ahead of the construction crews, clearing the access roads on the way in and checking the area under and around all the construction equipment before it was allowed to operate. Monitors surveyed the area around and in front of the equipment in the direction the equipment was working and checked all open excavations three or more times per day. The monitors also led the construction crews out at the end of the workday to clear the access road. Several monitors were tasked with "roving"— driving the access roads to clear them of desert tortoises in front of any vehicular traffic. These monitors were also available in the event of a construction crew having to split into two crews and requiring another monitor.

Modification to the monitoring plan

Kern River specifically timed construction in the winter months to avoid peak desert tortoise activity. By doing so, Kern River anticipated that construction-monitoring requirements for the desert tortoise would be reduced. The BO specifically provided provisions for this under Terms and Condition 1. (u), which allowed modifications based on regulatory approval. Based on weather patterns and the general absence of mobile tortoises during late October and early November, Kern River initiated a process of modifying the level of monitoring required. It was Kern River's position that the goals and requirements of the BO, as stated, were not to monitor individual pieces of equipment indiscriminately but, rather, to monitor work activities that may impact the resource and/or result in takes and, in general, to protect the resource in view of a number of variables. Because monitoring of tortoises necessarily needed to be a fluid activity, monitoring needs varied from day to day and even hour to hour. Kern River did not believe that the goal of the BO was to assign specific numbers of monitors to any specific

Table 1. Average number of monitors on a spread-by-spread basis

	Spread 6	7	8	9	10
Month					
October 2002	6	7	3	4	3
November 2002	9	9	5	14	15
December 2002	7	21	22	28	31
January 2003	2	31	31	33	36
February 2003	2	35	37	37	43
March 2003	1	21	32	19	27
April 2003	0	11	22	10	10

construction activity but that the goal was to assure complete and adequate coverage of all activities as determined by qualified biologists in consultation with the regulatory agencies.

The Lead Biologists were specifically approved by agencies with the understanding that they were experienced enough to make reasonable judgments as to the sufficiency of monitoring/acceptable compliance, with the concurrence of USFWS and state agencies. This interpretation, however, in some cases left uncertainty for some agency monitors who were tasked with monitoring or auditing compliance with the BO. To provide a set of measurable "black and white" guidelines, Kern River developed a protocol to establish when the reduced monitoring levels, envisioned by the BO, could be implemented by the Lead Biologists, based primarily on the resource rather than on more subjective views of what constitutes compliance. The protocols addressed levels of monitoring, definition of active/inactive season, and the modification of speed limits on primary access roads. Some agency staff, however, expressed concerns that written protocols would establish precedents for subsequent projects and, consequently, the definitions and levels of required monitoring finally approved in the protocols were quite conservative and to some extent did not provide significant flexibility in applying the terms and conditions of the Project permits. Additionally, because the detailed review and approval of Kern River's protocols took approximately 5 to 6 weeks, actual implementation of the protocols did not occur until the end of December, after significant construction had been completed and a significant portion of the inactive season had passed. As a result, monitoring levels remained at high levels throughout the duration of the construction process. Table 1 presents the average numbers of the monitors that were utilized each month on each of the Mojave Desert spreads throughout construction.

Monetary compensation

In addition to the requisite biological monitoring efforts during the course of construction, Kern River was also required to provide offsetting compensation for impacts to desert tortoise habitat. Compensation ratios were determined based on the extent of prior disturbance and whether the pipeline traversed critical desert tortoise habitat. As indicated earlier, the mitigation ratios of 1:1, 3:1, and 5:1 were established based on negotiations with all involved agencies. The ratios were established through application of a specific formula developed by the Desert Tortoise Compensation Team (1991) where

$$\text{the Compensation Rate} = C + T + E + G + A,$$

with C = Category of the habitat (Critical = 3/Non Critical = 1); T = Term of Effect (<10 years = 0/>10 years = 1); E = Existing Disturbance (Yes = 0/No = 1); G = Growth inducing effects (Yes = 0.5/No = 0); A = Adjacent habitat impacts (Yes = 0.5/No = 0).

All five factors are considered for critical habitat areas, but for non-critical habitat the ratio is set at 1:1. Because this prior compensation was committed to as part of the original pipeline in 1991, Kern River was of the opinion that the formula should be adjusted to account for this prior compensation, particularly in light of the combined mitigation of the two projects (up to a maximum mitigation ratio of 8:1) exceeding the maximum compensation required for a single high-impact project (6:1) that would eliminate tortoise habitat (i.e., construction of linear roadway). Additionally, based on the extensive restoration requirements built into the reclamation plan and the numbers of tortoises or burrows found in the existing ROW in 2002, Kern River believes that construction impact should in fact be considered short-term. While some agency staff agreed with Kern River, others refused to accept a lesser mitigation ratio and stated their approvals would not be issued. Further, the CSLC required the final mitigation to be part of the final environmental impact statement/environmental impact report (FEIS/EIR). Therefore, based on the truncated timeframe from which Kern River was operating to meet May 2003 in-service dates, Kern River accepted the ratios under protest.

Compensation ratios and rates and the upper limits of habitat disturbance for the desert tortoise in Nevada and Utah were presented in the BO. The estimated level of compensation was based on rate of $633 per acre of mitigation land. Table 2 summarizes the total mitigation payouts that Kern River committed to. The actual vehicles used to meet the requisite compensation requirements differed between the two states. In Utah, Kern River established a MOU with The Conservation Fund (TCF) to acquire suitable lands to offset impacts to desert tortoise habitat. In Nevada, payment was made directly to the Desert Tortoise Public Lands Conservation Fund, managed by the Clark County Department of Comprehensive Planning Habitat Conservation.

Specific California mitigation was outlined in the 2081 Permit. Impacts to BLM lands were compensated at a rate of $500 per acre in the eastern Mojave Desert and $700 per acre in the western Mojave Desert. Enhancement and endowment for the habitat mitigation lands for public lands were paid to CDFG at a rate of

Table 2. Kern River 2003 expansion project compensatory mitigation requirements

State	Actual construction impact (acres)	Mitigation requirements (acres)	Total cost
Utah	215.8	532.9	$380,109.50
Nevada	1,652	3001	$1,925,712.00
California	2,299.1	4,171	$4,623,230.40
Total			**6,929,051.9**

$295 per acre. For compensation of impacts on private lands, Kern River established a MOU with the Desert Tortoise Preserve Committee at a rate of approximately $1295 per acre.

Table 2 presents a summary of the final compensation required to offset impacts to desert tortoise habitat.

LESSONS LEARNED

Efficacy of the monitoring

Mitigation measures implemented by Kern River were more than adequate to ensure that there were no negative impacts to sensitive species. During the course of construction, only a single desert tortoise take was attributed to Project activities. In comparison, construction of the original pipeline in 1991 resulted in approximately 30 takes. This can be attributed to both the monitoring that occurred as part of the 2003 Expansion Project and to the timing of the construction activity to coincide with the desert tortoise inactive period of the colder winter months. The wildlife surveys provided 100% coverage of the ROW footprint and 50-foot buffer zones prior to construction. All empty burrows potentially usable by desert tortoises were collapsed to prevent reentry before beginning clearing and grading activities. This ensured that no sensitive species were in that footprint, since ROW clearing occurred during the desert tortoise's dormant season. Qualified biologists monitored all equipment activity to avoid impacts to active tortoise. No burrows or pallets were found in the footprint after the wildlife survey had been completed. Little tortoise activity was noted during the inactive season.

Based on the data collected during construction, monitoring of certain construction activities and segments could be considered excessive, particularly on the activities isolated on the ROW following clearing and grading of the ROW. With few exceptions in the more active season, the monitors overseeing ditching, stringing, welding, and lowering-in crews identified no tortoises. Because of specific monitoring requirements, Kern River was required to utilize as many as 20 to 30 biologists on the ROW to monitor specific activities, even during the periods of relative inactivity, while data showed that the vast majority of the tortoises identified outside the pre-construction surveys were either found along access roads or well outside the construction zone by roving monitors.

As temperatures increased and rainfall increased, tortoise activity increased. With the exception of Spread 10, which had atypically warm conditions coupled with periods of increased moisture; clearing and grading activities were largely completed in the inactive season. During the inactive season, tortoises were found primarily in burrows, in conjunction with pre-construction surveys. As the tortoises become more active, the roving monitors or "rovers" were most critical in preventing tortoises from being hit on access roads by either construction or non-construction traffic. Kern River also implemented an incentive program for construction contractor personnel. Individuals received $100 for reporting a tortoise in their work area. Workers could only receive this money if they informed a monitor of their find and all standard tortoise protection procedures were met. This effectively added hundreds of employees watching for tortoises and the program was very successful.

With the onset of increased tortoise activity in April, Kern River implemented additional protection measures above and beyond the extent of the BO to maximize the protection of the tortoise. All personnel and equipment were regularly escorted into the work site by a monitor, and monitors at stationary jobs (i.e., valve stations) walked the access roads more frequently. The numbers of tortoises seen after mid-April demonstrated the value of these efforts.

Access road speed limits

During the course of coordinating with agencies on the permit requirements, a defined speed limit on all access roads was considered non-negotiable, and a speed limit of 20 mph was assigned to all non-county maintained, unpaved access roads.

Based on the results of the monitoring, the need/efficacy of an established 20 mph speed limit is questionable as a carte blanche application to an entire project. Kern River notes the value of a speed limit when tortoises are potentially present and mobile. This was most notable in the later months of construction when the majority of tortoises were found on the access roads. However, where little or no tortoise activity is noted, the 20 mph can significantly decrease construction progress and raise construction costs. Because of the remoteness of large portions of the 2003 Expansion Project ROW, and the length of some of the access roads that provided the primary ingress and egress to the ROW, drive time for crews was significantly increased by the lower speed limit. With specific reference to the stringing activities, a decreased speed limit, in fact, reduced the productivity of the spread, pushing the spread into the warmer months and increasing the potential for incidental take.

Table 3. Numbers of desert tortoise found during 2003 expansion project monitoring

		2002 Sept.	Oct.	Nov.	Dec.	2003 Jan.	Feb.	Mar.	Apr.	May
SPREAD										
	Access Road	1	–	–	–	–	–	–	–	–
6	ROW*	–	–	–	–	–	–	–	–	–
	Off-ROW**	–	–	–	–	–	–	–	–	1
	Access Road	1	–	–	–	2	3	8	17	15
7	ROW*	–	2	3	2	7	5	4	12	1
	Off-ROW**	–	2	–	–	2	3	4	1	1
	Access Road	2	2	–	–	–	1	8	36	82
8	ROW*	2	2	4	5	11	7	14	50	47
	Off-ROW**	–	1	–	–	–	3	1	12	–
	Access Road	–	–	–	3	2	11	34	35	1
9	ROW*	–	1	7	7	6	6	7	2	–
	Off-ROW**	–	2	–	4	4	8	7	–	–
	Access Road[(a)]	–	–	–	–	–	–	1	(b)	(b)
10	ROW*	–	8	30	12	8	5	6	(b)	(b)
	Off-ROW**	–	–	7	44	126	41	20	(b)	(b)

* – ROW – Tortoise found either within the ROW or 50-foot buffer zone.

** – Off-ROW – Tortoises found by monitors beyond the 50-foot buffer zone.

(a) – Spread 10 closely parallels existing roads negating the need for significant access roads.

(b) – The need to remove all flagging and marking prevented an accurate count of tortoises found in April and May.

Monitoring costs and level of effort

To adhere to the monitoring requirements spelled out in the BO, Kern River utilized as many as 160 tortoise monitors during the peak construction period. Based on the levels of effort expended on construction biological oversight, it is estimated that costs for tortoise monitoring alone to be:

- Utah – $600,000
- Nevada – $7,500,000
- California – $8,500,000

To put these figures into more contexts, the 2003 Expansion Project traversed approximately 13.8 miles of desert tortoise habitat in Utah, 120.5 miles in Nevada, and 184.5 miles of habitat in California. To cross reference the project expenditures with the levels of effort, Table 1 provides the average staffing of tortoise monitors on the Project and Table 3 presents the numbers of tortoises located, categorized by spread and month. Based on direct observation during the course of the construction, significant reductions in tortoise monitoring would be possible without compromising the protection of the tortoise. As demonstrated in Table 3, tortoises were most active during the later portions of construction when climate conditions were more conducive. Those tortoises that were found during the inactive period were largely found in burrows on the ROW during the course of the preconstruction survey. In a few instances tortoises were found outside burrows during the seasonal period of inactivity. Based on direct observation by qualified biologists, these tortoises likely had contracted Upper Respiratory Tract Disease (URTD), and their unusual behavior was due to the disease.

The data collected during the construction phase suggest that tortoise-monitoring requirements on future projects can be modified to reflect in-field conditions. Specifically, the data showed specific areas that corresponded with higher tortoise activity and areas that lacked tortoise activity or tortoise sign. However, based on the terms and conditions set forth for the project, Kern River had little flexibility in reducing tortoise monitoring. FERC and BLM monitors on site were bound to interpret the adequacy of tortoise monitoring based on the specifications of the BO and 2081 Permit or, at times, more subjectively or based on precedents set on other projects. These factors often took precedence over the more discretionary, professional judgment of the qualified Lead Biologists, which Kern River believed the BO had intended. The concurrent construction of five spreads also minimized the effectiveness of proposing specific modifications on a Project-wide basis due to varied conditions, and would have added undue hardship for these monitors to apply the Permit conditions consistently across all five spreads. The estimated monitoring costs presented above, coupled with the actual tortoises found, shows that Kern River spent $600,000 on monitoring in Utah, even though only two tortoises were found. Only a single tortoise was found during the preconstruction surveys, and a second tortoise was found during a downstream survey of a hydrostatic test water discharge location well away from the ROW. This particular spread was also largely completed in the winter season, avoiding more active tortoises. Because of the apparent low density of tortoises in Utah, protection of these tortoises may be even more paramount in maintaining a stable population base. However, the return provided by the monitoring would suggest that excessive monitoring occurred.

On spreads 7 through 10, where greater tortoise numbers were found, the data again show little to no tortoise activity through the colder winter months. Activity levels increased as temperatures increased, the moisture increased with the winter rains and the desert greened with annual plant growth. Recognizing the increase of tortoise activity, the Lead Biologists actually increased the monitoring levels above that required in the permits to better monitor high-risk areas. Because of the limited interpretation of the permit conditions, this required bringing on significantly more monitors to not only meet the permit requirements but to also assure adequate protection of the desert tortoise. By providing the Lead Biologists with greater flexibility in assigning monitors to specific tasks, Kern River is confident that adequate monitoring could have been accomplished with far fewer monitors. Specifically this would have involved reducing the monitoring on the ROW for the spread activities with the lowest potential for impact to the tortoise, reducing levels of monitoring during the tortoise inactive season, and determining monitoring needs based on the resource itself rather than strict compliance with the terms and conditions of permits intended for the active season construction.

CONCLUSIONS

The mitigation measures implemented by Kern River were very effective at minimizing impacts to the desert tortoise during construction of the 2003 Expansion Project. The most telling evidence of the effectiveness is that only a single take occurred as a result of Project activities. Because of the fast-track permitting schedule for this project, Kern River had limited opportunity to negotiate permit conditions while still maintaining its aggressive schedule. To the knowledge of the authors of this paper, little or no recent data were available detailing tortoise activity either spatially or temporally with a project of the magnitude of the Kern River 2003 Expansion Project. As such, any significant modifications to permit conditions would have to have been made based on anecdotal evidence instead of hard data. Any agency developing mitigation protocols must base their decisions on best available information. While significant data exists with respect to tortoise biology, little data were available directly tying potential impacts and tortoise biology to a project of the magnitude of Kern River project. Therefore, the agencies (FERC, BLM, resource agencies) had little recourse other than to develop mitigation requirements based on the current state of the science and precedent set on other projects and to assess the success of a monitoring program against very defined and rigid ("black and white") standards. As should be generally recognized, biology does not operate in "black and white" but rather in "shades of gray." This makes decision-making somewhat subjective and open to opinion. Recognizing that any significant permit modifications could be precedent setting for future similar projects, the agencies realistically did not have the needed data to make critical modifications to the permits that could directly impact the long-term protection of the desert tortoise.

It is our hope that data collected during the 2003 Expansion Project and submitted to the agencies as part of the post-construction reporting requirements can provide the hard data needed by agencies to provide additional flexibility in future projects by developing standards or conditions based on the resources and nature of each particular project. Kern River is committed to protection of all sensitive resources potentially impacted by pipeline construction. However, Kern River, as any other capital developers, would be interested in establishing more realistic mitigation requirements need to protect a species.

ACKNOWLEDGEMENTS

Special acknowledgements are extended to Kern River for their commitment and support of mitigation for the Desert Tortoise, as well as to the cooperation of the FERC staff, USFWS, BLM, CDFG, and other involved agencies. The cooperation and compliance demonstrated by its contractors is also appreciated. Acknowledgement is also provided to monitors provided by Ecology and Environment, Inc., Southern Nevada Environmental, Inc., and Garcia and Associates for diligently collecting and recording data during the construction of 2003 Expansion Project.

REFERENCES

California Department of Fish and Game. California Endangered Species Act Incidental Permit No. 2081-2002-005-06. Kern River Gas Transmission Company, 2003 Expansion Project.

Desert Tortoise Compensation Team. 1991. Compensation for the Desert Tortoise. A Report Prepared for the Desert Tortoise Management Oversight Group.

Federal Energy Regulatory Commission and California State Lands Commission. 2002. Final Environmental Impact Statement/Environmental Impact report. Volume 1. Kern River 2003 Expansion Project. FERC/EIS-0144 Docket No. CP01-422-000 CSLC EIR No. 710 State Clearing House No. 2001071035 BLM Reference Nos. CACA-43346 CACA 17918.

Fish and Wildlife Service. Biological Opinion and Request for Concurrence with Effect Determination for Listed and Proposed Species Associated With the Kern River Gas Transmission Company Project in California, Nevada, Utah, and Wyoming, Docket No. CP01-422-000.

Fish and Wildlife Service. 1994a. Desert tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland Oregon.

Fish and Wildlife Service. 1994b. Proposed Desert Wildlife Management Areas for Recovery of the Mojave population of the desert tortoise. U.S. Fish and Wildlife Service, Portland Oregon.

Kern River Gas Transmission Company. 2003a. Kern River 2003 Expansion Project, Project Summary Report Spread 6. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003b. Kern River 2003 Expansion Project, Project Summary Report Spread 7. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003c. Kern River 2003 Expansion Project, Project Summary Report Spread 8. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003d. Kern River 2003 Expansion Project, Project Summary Report Spread 9. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2003e. Kern River 2003 Expansion Project, Project Summary Report Spread 10. Prepared by Ecology and Environment, Inc.

Kern River Gas Transmission Company. 2001. Desert Tortoise Assessment. Mojave Desert Tortoise Population. Utah, Nevada, and California. Kern River 2003 Expansion Project. Prepared by Ecology and Environment, Inc.

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Management of Power Line Easement Vegetation for Small Mammal Conservation in Australia: A Case Study of the Broad-toothed Rat (*Mastacomys fuscus*)

Donna J. Clarke and John G. White

Within Australia, very little attention has been given to the potential biodiversity benefits of power line easements, if ecologically sensitive management regimes are developed. This study examined the potential power line easements may have for the conservation of small mammals, and in particular the near threatened, Broad-toothed Rat Mastacomys fuscus, in Australia. Easement vegetation was found to support a diverse small mammal community, including M. fuscus if the vegetation was allowed to develop some structural complexity. M. fuscus was one of the first species to recolonize the easement habitat, provided that the areas had regenerated to a sufficient level. Results suggests; however, that the current management technique used, where the entire easement is managed at one time via mass slashing, on short rotation times, is most likely limiting M. fuscus to low abundances, and causing isolation of the current M. fuscus populations. To ensure that power line easements supply functional, usable habitat for small mammals and other species and to minimize their potential to fragment small mammal populations, it is recommended that current management techniques be reassessed. In an effort to develop more appropriate management regimes, it was recommended that rotation times be increased between management, that mass slashing of the easement at one time be reassessed, especially in naturally low growing areas and that rotational type slashing be implemented. Other techniques such as spot spraying, may be all that is needed within some areas to control emergent saplings. This study highlights that potential biodiversity values do exist for Australian power line easements, if some changes occur to the current management practices.

Keywords: Power line easement, Broad-toothed Rat Mastacomys fuscus, Australia, wildlife management, right-of-way

INTRODUCTION

Power line easement management in Australia has focused extensively on the reduction of fuel loads to minimize the risk of damage to transmission lines and pylons during wildfire. Management has largely been in the form of slashing on a frequent basis and in some case with the application of dicot specific herbicides. This type of management has ultimately created early successional edge habitat within the easement, with low structural diversity and no canopy cover (Goldingay and Whelan, 1997; Goosem and Marsh, 1997). The use of dicot specific herbicides further effects the vegetation by reducing the diversity of plant species in the easement (Brown, 1995).

Within Australia, limited research has focused on the ecological changes resulting from the long-term management of forest clearings for power line easements and rights-of-way (ROW) (e.g. Baker et al., 1998; Goldingay and Whelan, 1997; Goosem, 2000; Goosem and Marsh, 1997). As a result, there is restricted knowledge regarding ecological changes that occur in forest divided by power lines, in Australia. Given the single minded focus on fuel reduction, very little attention has been given to what potential benefits there may be

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for biodiversity if ecologically sensitive management regimes are developed.

Research from Northern Hemisphere systems (e.g. Chasko and Gates, 1982; Hanowski et al., 1993; Smallidge et al., 1993) has suggested that easements and ROWs through forests can have potential biodiversity benefits. For example, rare and endangered species have been found to use the openings created by easements and ROWs, such as the Karner Blue Butterfly (Smallidge et al., 1996).

Concerns have been raised over the possible effects ROW service roads may have on local small mammal populations. Forest dependent species may be reluctant to cross even small areas of open habitat, especially where there is a lack of canopy cover (Goosem, 2000). Much literature has focused on the fragmentation of small mammal habitat by roads (e.g. Andrews, 1990; Dunstan and Fox, 1996; Goosem, 2000) and on the barrier effect roads can have on small mammal movements (e.g. Barnett et al., 1978; Burnett, 1992; Oxley et al., 1974). Small mammals have been found to be sensitive to even small tracks (Barnett et al., 1978). The potential does exist therefore, for power line ROWs to separate small mammal forest communities (Goldingay and Whelan, 1997; Kozakiewicz, 1993; Macreadie et al., 1998).

Until recently, research in Australia has suggested power line clearings are largely invaded by generalist, grassland species, many of which are exotic (Goosem, 2000; Goosem and Marsh, 1997), and may not necessarily provide benefits to biodiversity. This may be a consequence of the extensive management regimes in place in Australia. A recent study conducted in Australia; however, detected a population of the near threatened small mammal species, the Broad-toothed Rat *Mastacomys fuscus*, living within power line easement vegetation (Macreadie et al., 1998). The presence of this species within the easement led to questions being asked about the potential role power line easements and ROWs may play for biodiversity within Australia and highlighted the need to examine the effect of current management regimes on *M. fuscus* and other small mammal species.

THE BROAD-TOOTHED RAT *MASTACOMYS FUSCUS*

Mastacomys fuscus (Rodentia: Muridae) is a diurnal, specialist herbivore, which feeds primarily on grass (Carron et al., 1990; Strahan, 1995). Breeding in this species is seasonal, and depends on the location, and elevation above sea level of the population. *M. fuscus* have a low fecundity compared to other native small mammals in Australia, producing litters of only 1–3 young, after a 5 week gestation period (Strahan, 1995; Taylor, 1984).

M. fuscus characteristically occurs in alpine and subalpine heath, dominated by grass and sedge species, but inhabits a wide range of habitats such as open eucalypt woodland, clearings with dense undergrowth through wet schlerophyll forest and wet sedgelands (Brunner et al., 1977; Green and Osborne, 1990; Strahan, 1995; Taylor, 1984). *M. fuscus* occurs in disjunct populations in Victoria, Tasmania, the Australian Capital Territory and the alpine regions of New South Wales, Australia (Seebeck, 1971; Strahan, 1995). Fossil records indicate that *M. fuscus* was once more widespread than its current range (Seebeck, 1971; Strahan, 1995). Modification and loss of habitat, and predation by feral, introduced species, especially the Red Fox (*Vulpes vulpes*), are thought to be the major processes contributing to the decrease in *M. fuscus* numbers (Green, 2003; Green, 2002; Seebeck and Menkhorst, 2000; Strahan, 1995). Currently, *M. fuscus* are classified as Lower Risk – Near Threatened in Victoria (Museum Victoria, 2002) and are protected under the National Parks and Wildlife Act 1971, in Tasmania (Hocking and Driessen, 2000). They are Vulnerable in New South Wales (Green, 2000), but have no special protection status in the Australian Capital Territory (Green and Osborne, 2003).

STUDY AREA

Bunyip State Park is located 65 km's south-east of Melbourne, in Victoria, Australia and covers 16,560 hectares (Fig. 1). The double 500 kV transmission line was established in 1962 and crosses approximately 300 km of the state of Victoria, 10 km of which extends through the northern section of Bunyip State Park (Parks Victoria, 1998).

The easement within Bunyip State Park ranges from 100–120 m wide, including an approximately 5 m wide dirt, service road which run the length of the easement, which often cuts through the vegetation. The easement is dominated by heathland vegetation, consisting of native shrubs, sedge and grass species and currently is managed on a 3 year rotation. The management regimes involve mass slashing of the entire easement and spot spraying of emergent shrubs where necessary. Wet gully areas where machinery cannot access, generally are left unmanaged. Areas that are too steep for the slashing machinery to access commonly are cleared of all vegetation via bulldozing. The majority of the easement vegetation was slashed to a height of approximately 5 cm, in September 2000.

The detection of M. fuscus by Macreadie et al. (1998) under the transmission lines in Bunyip State Park, lead to the protection of an area from complete vegetation removal by Parks Victoria and SPI PowerNet. This area currently is managed through limited spot spraying of emergent trees. Although the protected area is only one span between pylons (approximately 500 m × 100 m), it reflects a shift away from the "slash and trash" type management and a move towards acknowledgement of the potential biodiversity values associated with power line clearings through forests.

Fig. 1. Location of study area, Bunyip State Park, Victoria, Australia.

METHODS

Trapping

Three permanent sites were established along the 100 m wide power line easement dissecting Bunyip State Park, Victoria, Australia. Two sites were established in areas where the easement had been slashed in September 2000. A reference site was also established in the protected area, which had not been slashed since approximately 1994, where there was a known population of *M. fuscus*. At both the reference site and the first managed site, the service road cut through the middle of the easement. The service road within the second managed site was on the edge of the adjacent forest and did not dissect the easement. Each trapping grid spanned 125 m × 300 m incorporating both the power line easement and the adjacent forest vegetation. One hundred and two Elliott traps were set at each site, for five consecutive nights and were cleared every morning. Thirty traps were placed in the easement and 36 traps were set either side, in the adjacent forest, with 25 m spacing used between transects and 20 m between traps. Cotton wool was added to traps for insulation against cold temperatures. Traps were baited with a mixture of rolled oats, peanut butter, honey, tuna oil and linseed oil. Captured animals were identified to species, with head-body length measured, reproductive condition and location on the grid recorded. All rodent species were ear tagged for identification purposes, or if already tagged, the number recorded. All other species were ear notched. All animals were released at point of capture. Fieldtrips were conducted once a month, every month from January 2001, until May 2002 and every two months until January 2004.

Vegetation surveys

Vertical vegetation structure estimates were used to assess the differences in vegetation at each site, as many researchers have demonstrated the importance of habitat structure for small ground-dwelling mammals (e.g. Bennett, 1993; Fox et al., 2003; Fox and Fox, 1984; Monamy and Fox, 2000), with much of the small mammal literature suggesting structure is the major influence on small mammal occurrence (Monamy and Fox, 2000), rather than vegetation diversity.

Vertical vegetation structure was measured using a 2 m pole, divided into 10 cm increments. The pole was placed vertically at ground level with the number of contacts by vegetation, being recorded at each increment. A maximum of 10 touches were recorded for each increment. This value was averaged across each site for each survey period to give an index of vegetation structure between 0 and 10, with 0 being no vegetative cover and 10 being dense forest coverage. Five vegetation structure assessments were conducted around each trap location. These were executed at random points within a 5 m × 5 m quadrant.

Due to the drought conditions experienced in Australia over the period of the study, the time intervals between vegetation surveys varied. Vegetation surveys within the easement were conducted at random time intervals up until January 2003, where a noticeable change in vegetation growth resulted in surveys being conducted every 3 months, until January 2004. Forest vegetation surveys were conducted annually in 2001–2003.

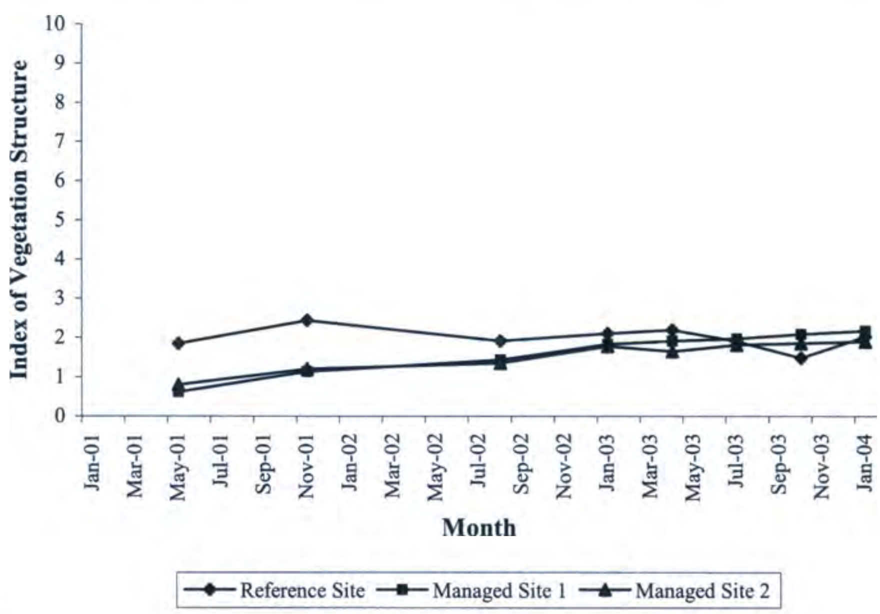
Data analysis

Paired t-tests based on trap success, were used to assess if any differences existed in species preference for forest or easement habitat. The trap success measure was used to ensure that no bias existed in the results, due to the different number of traps set in the forest and easement habitat. A one way ANOVA was also used to assess any differences in the vegetation indices for the easement vegetation across the study. All analysis was conducted using Statistical Package for the Social Science (SPSS) software package.

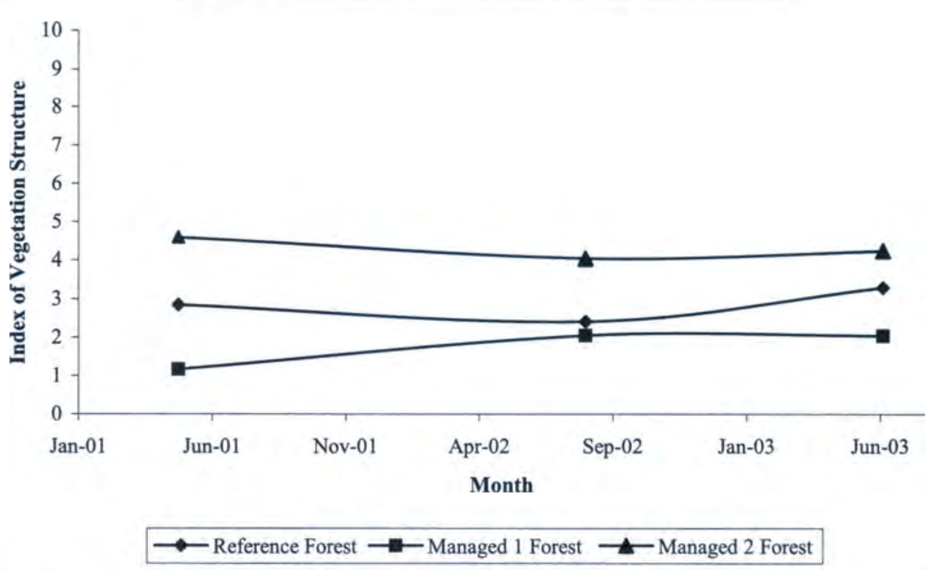
RESULTS

Index of vegetation structure

As would be expected, the vegetation within the easement at sites that had been slashed in 2000 changed in structure over the time of the study (Fig. 2a), however the forest vegetation index remained fairly constant (Fig. 2b). The forest indices reflect the general grassy,



(a)



(b)

Fig. 2. Change in the index of vegetation structure within the (a) easement and (b) surrounding forest, post slashing, from May 2001 to January 2004.

openness of the forests surrounding the easement, and were not expected to change much over the study.

The easement vegetation at the reference site remained fairly constant over the study; however, the drop shown in vegetation structure in March to September 2003, was due to destruction of a section of vegetation by 4 wheel-drive vehicles. The increase in vegetation after this date was to due to management actions taken by Parks Victoria to reduce any further impact on the easement at this site by recreational users. Management actions taken by SPI PowerNet also resulted in a widening of road verges over the period of the study, which most likely contributed to changes in vegetation indices at all sites.

Vegetation within the slashed sites, reached an index similar to the reference site around January 2003, and structure indices between sites became almost indistinguishable by June 2003, almost 3 years after slashing had taken place at these sites (Fig. 2). Although there were clear physical differences between easement vegetation of the three sites, there was no significant statistical difference between the easement vegetation indexes for all three sites when data was pooled across the survey periods ($F = 1.926$, $p > 0.05$). This highlights that the vegetation indices is only a broad measure used for a quick comparison and may not be sensitive enough to detect small differences between easement vegetation.

Trapping of *M. fuscus* and other small mammals in Bunyip State Park

Overall there were 5,939 captures of eight native and one introduced small mammal species across the easement and forest habitat, over 35,190 trap nights. The most commonly trapped species was the Dusky Antechinus *Antechinus swainsonii* (1810 captures), followed by the Agile Antechinus *A. agilis* (1531 captures), the Bush Rat *Rattus fuscipes*, (1237 captures) and the Swamp Rat *R. lutreolus* (1046 captures). Lower capture rates occurred of House Mouse *Mus domesticus* (110 captures), Eastern Pygmy Possum *Cercartetus nanus* (56 captures), Southern Brown Bandicoot *Isoodon obesulus* (8 captures), and Long-nosed Bandicoot *Permeles nastua* (3 captures) (Table 1). The high species richness found in the easement suggests that a number of common species have benefited from the presence of the easement. Although there was a high species richness found in the easement, only *M. domesticus* was

Table 1. Number of individuals of each species captured in the forest and easement habitats, at all sites. Numbers in the parentheses indicate number of individuals at each site

Site	Species	Forest	Easement	*t*	*p* value
Reference Site	*Rattus lutreolus*	147(16)	211(42)	1.455	0.205
	Mastacomys fuscus	1(1)	114(18)	3.086	0.027#
	Rattus fuscipes	335(44)	79(10)	−1.934	0.111
	Antechinus swainsonii	576*	179*	−1.982	0.104
	Antechinus agilis	506*	119*	−2.266	0.073
	Cercartetus nanus	46(13)	1(1)	−5.838	0.002#
	Isoodon obesulus	3(3)	1(1)	ID	ID
	Permeles nastua	0	0	ID	ID
	Mus domesticus	0	10(4)	ID	ID
Managed Site 1	*Rattus lutreolus*	21(8)	51(14)	0.721	0.503
	Mastacomys fuscus	0	21(2)	1.543	0.183
	Rattus fuscipes	109(22)	0	−3.858	0.012#
	Antechinus swainsonii	241*	11*	−6.933	0.001#
	Antechinus agilis	396*	2*	−12.826	0.00#
	Cercartetus nanus	6(2)	0	ID	ID
	Isoodon obesulus	0	0	ID	ID
	Permeles nastua	1(1)	0	ID	ID
	Mus domesticus	0	41(18)	4.564	0.006#
Managed Site 2	*Rattus lutreolus*	580(100)	36(10)	6.666	0.001#
	Mastacomys fuscus	0	2(1)	ID	ID
	Rattus fuscipes	712(79)	2(2)	9.001	0.00#
	Antechinus swainsonii	764*	39*	8.643	0.00#
	Antechinus agilis	493*	15*	13.727	0.00#
	Cercartetus nanus	3(2)	0	ID	ID
	Isoodon obesulus	4(4)	0	ID	ID
	Permeles nastua	0	2(1)	ID	ID
	Mus domesticus	1(1)	58(26)	−3.726	0.014#

* indicates number of captures only
ID indicates insufficient data for analysis
\# indicates statistical significant difference

found to have statistically higher numbers in the easements at the managed sites ($t = 4.564, p < 0.05$ for managed site 1; $t = -3.726$, $p < 0.05$ for managed site 2) (Table 1). This suggests that the current management of the easement may be removing all resources for native species and opening up the landscape for introduced species. This is emphasized further by species that were commonly trapped in the easement of the reference site, such as *R. lutreolus*, *A. swainsonii*, and *A. agilis*, having low capture rates in the managed easements, and statistically higher numbers in the surrounding forest at these sites (Table 1). This highlights that native species will utilize the easement when the resources are available, but cannot use the easement when all the vegetation has been removed. It also shows that there is a source population for recolonization of the easement, within the surrounding forest. *C. nanus* was the only species trapped at significantly higher numbers in the reference forest ($t = -5.838$, $p < 0.05$).

The near threatened species, *M. fuscus* generally only occurred in the easement habitat. They were captured in low densities, which suggests that current management regimes may not be suitable for population growth in this species. There were 138 captures of 21 individual *M. fuscus*. All captures except one, occurred in the easement habitat. The majority of captures (83.3%) occurred in the reference site, where minimal management had occurred for ten years and therefore it is no surprise this species was trapped significantly more in the easement habitat at this site ($t = 3.086$, $p < 0.05$), than the surrounding forest. Low numbers of *M. fuscus* were trapped at the recently managed sites, with 15.2% and 1.5% of captures occurring at these two sites. A sex bias was observed in the numbers of individual *M. fuscus* trapped. The sex ratio among individuals was approximately 3:1, with 16 females and five males, being trapped over the study. Overall, female captures made up 85.5% of captures and males only 14.5% of overall captures.

R. lutreolus and *R. fuscipes* were first trapped in the easement at managed site 2 in March 2002, 18 months after management (Fig. 3). *R. lutreolus* was also the first rodent species trapped in the easement at managed site 1, in July 2002, almost 2 years after management (Fig. 3). The first *M. fuscus* trapped outside of the reference site occurred at managed site 1, in November 2002, over 2 years after slashing had taken place at this site. One individual *M. fuscus* was trapped at the second managed site, in January 2004, over 3 years since management had occurred at this site (Fig. 3).

M. fuscus tended to be captured as adults. Only four individuals were first captured as a juvenile, which may be an indication of trap-shyness in this species, or may be an indication that adults of the species are moving into the easement from other areas within the Park.

Breeding of *M. fuscus*

To determine if the easement was proving functional habitat for *M. fuscus*, and to determine the times of the year the population would be sensitive to disturbance, the months that females were pregnant, was assessed. *M. fuscus* bred all years within the study. Overall, a third of the individual females were found to breed over some stage of the study. All of the males were trapped in a mature reproductive condition. Most breeding activity occurred between November and February; however, two pregnant females were caught in September 2001 and 2003. One female caught in August 2001 was also found to be pregnant. Data suggested that *M. fuscus* may be able to produce more than one litter over this time, with one female producing at least two litters in the 2001 breeding season. There was not enough data; however, on the other females *M. fuscus* to detect if they produced more than one litter over a breeding season. The presence of pregnant females in the easement suggests that the easement is providing functional habitat for this species.

Spatial organization and movements of *M. fuscus*

Trap usage by *M. fuscus* was found to differ between years. In 2001, 20% of traps caught more than one individual *M. fuscus*, 30% of traps caught more than one individual in 2002 and 3.3% of traps caught more than one individual in 2003 (Fig. 4). This indicates that there is some overlap in habitat utilization by individuals at the reference site and additionally suggests that there is some overlap in individual home ranges, especially between females.

The percentage of traps in the easement that did not catch any *M. fuscus* (40% of traps in 2001, 43.4% of traps in 2002 and 55.6% of traps in 2003) indicated that there were areas of the easement, which were not suitable for this species. This possibly may be due to either other sympatric species, such as *R. lutreolus* or *R. fuscipes* using these resources, or because the necessary structural attributes were not present. This highlights; however, that in all years, except 2003, where recreation vehicles destroyed a key section of the easement, *M. fuscus* were able to utilize more than half of the easement habitat.

Overall, 6 of the 30 (20%) traps never caught any *M. fuscus* at the reference site. Four of these trap stations were close to the edge of the forest, where there was little vegetative cover. Based on observation, these trap stations were often surrounded by leaf litter and generally were more open grassy areas than the rest of the easement at this site. Trap usage did shift slightly from year to year; however, 6 of the 30 traps caught *M. fuscus* every year across the study, 4 of which were in close proximity to the service road. Based on observations, these trap stations generally were surrounded by dense native sedge and grass species. This suggests that vegetation density and cover may be important for this species, and may suggest the importance of native

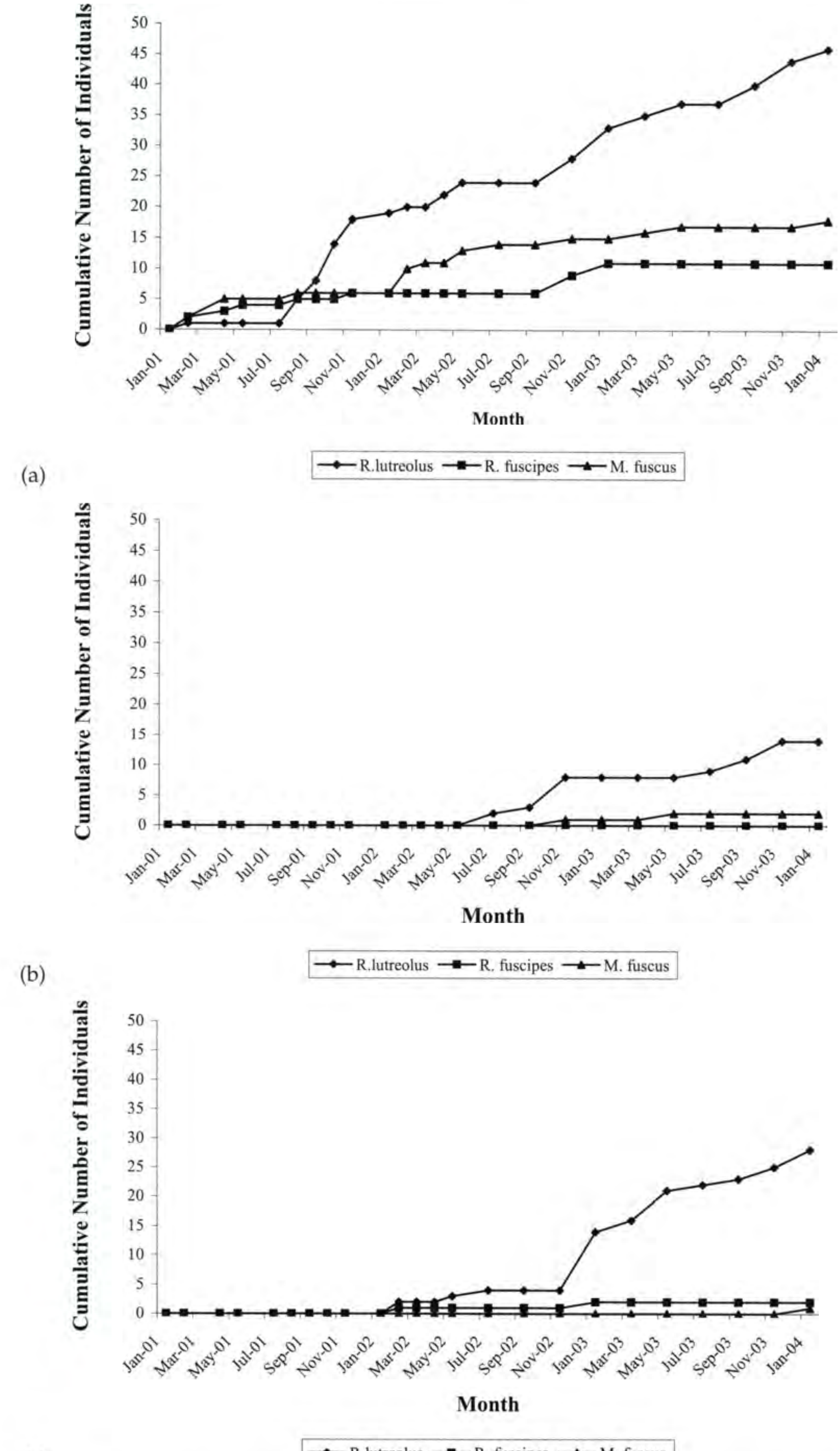


Fig. 3. Cumulative number of individual *R. lutreolus*, *R. fuscipes*, and *M. fuscus* trapped across the study period at (a) the reference site, (b) managed site 1 and (c) managed site 2.

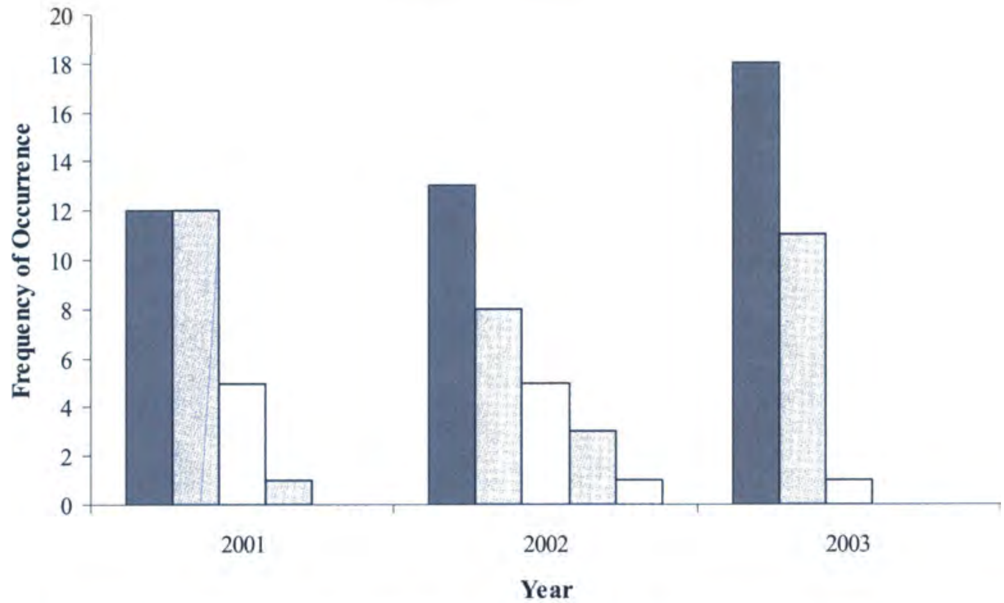


Fig. 4. Trap usage (out of 30 traps) of *M. fuscus* in 2001(a), 2002(b) and 2003(c) at the reference site. Dark grey bars represent the number of traps where no individuals were caught, horizontally striped bars represent the number of traps, which only trapped one individual, spotted bars show the number of trapped where two individuals were caught, diagonal stripped bars represent the number of traps three individuals were caught and the white bars represent the number of traps where four individuals were caught.

sedges and grasses for *M. fuscus*. Overall, a large contiguous area of the easement was used by this species across the study, accounting for 80% of the easement at the reference site.

Female *M. fuscus* movement between captures ranged from 0–102 m, with an average movement between captures of 30.13 m. The range of pregnant females was smaller (0–75 m), as was their average movements between captures (23.7 m). The movement range of female *M. fuscus* suggests they have the ability to move distances great enough to be able to recolonize suitable habitat.

Six individual *M. fuscus* also crossed the service road at least once, over the course of the study. This is a significant finding, as it suggests that the service road does not represent a barrier to movement of this species and therefore, does not separate the population of *M. fuscus* into two disjunct populations within the easement.

DISCUSSION

Easement vegetation is able is support a diverse small mammal community, provided that destructive management techniques are minimized, and that vegetation is allowed to develop some structural complexity. The high numbers of the *Rattus* sp. and *Antechinus* sp. in the reference easement shows that if the easement is allowed to retain some structural complexity after management, easement habitat can support a high diversity of small mammal species. The high species richness found in this study also highlights that a wide range of small mammals are able to utilize the easement habitat, and suggests that easements may provide functional habitat for some species, such as *R. lutreolus*, *M. fuscus* and *Antechinus* sp. Power line vegetation can provide alternative, early successional habitat for species that occur at lower densities in the surrounding forest. Ecologically sensitive management regimes would ensure that these areas are able to sustain stable small mammal populations.

Mastacomys fuscus

The almost exclusive selection of the easement habitat by the near-threatened Broad-toothed Rat *Mastacomys fuscus*, emphasizes that easements do have potential biodiversity values within Australia. The absence of *M. fuscus* captures in the forests, suggests that they are largely restricted to the easement habitat, and emphasizes further, the importance of appropriate management techniques.

The current management of the entire easement by mass slashing, on a three year rotation, is most likely limiting *M. fuscus* to low abundances, isolating current *M. fuscus* populations to areas within suitable habitat, that is not managed, and restricting the colonization of this species to other areas within the easement. This study shows that *M. fuscus* is capable of colonizing other areas within the easement, at Bunyip State Park, provided that the areas are left to regenerate to a sufficient level. *M. fuscus* colonization of one managed site in January 2004, over 3 years since management, highlights the need for longer rotation times between slashing. The short rotation times currently in place, appears to be responsible for the lack of colonization of this species through the easement. Based on the current slashing regime, the easement would be slashed at a time when *M. fuscus* are attempting to colonize the area. By removing the vegetation and consequently the cover and food resources from the easement, the attempts of *M. fuscus* and other native small mammals species, to establish stable populations are hindered. The current management regime therefore, is not ecologically sensitive and is counter productive, as the easements are only just beginning to be re-colonized by small mammals, at a time when all vegetation and resources are removed. Lengthening rotation times between major management events would allow small mammals to establish stable populations within the easement vegetation, especially as it took the more common native species 18 months to 2 years to start using the easement following management. This highlights the need to assess the vegetation under the transmission line to determine if management is necessary or appropriate, instead of having pre-determined rotation times, especially in naturally low-growing vegetation. The lack of change in the reference site vegetation indices suggests that the vegetation community is fairly stable and does not require maintenance beyond selective cutting or spot spraying of emergent shrubs. This suggests that there is potential for stable communities to exist within the easement, and further implies that the use of spot spraying, selective cutting and longer rotation times may be achievable.

Despite the low numbers of *M. fuscus* trapped in the easement, their presence was encouraging, as *M. fuscus* had not been detected previously at the two managed sites. Green and Osborne (2003) pinpoint that the food and protection from predators provided by the structural features of the habitat, limit *M. fuscus* numbers. The easement at one site was just beginning to have the structural features required to support a *M. fuscus* population, 2 years after management. *M. fuscus* consequently do not necessarily require high growing vegetation and it is therefore viable to maintain core habitat for *M. fuscus* populations within the easement, without compromising management objectives, or greatly increasing risk to pylon integrity or power supply during wildfire.

Loss of habitat is one of the major causes of decline in *M. fuscus* population numbers (Green and Osborne, 2003; Seebeck and Menkhorst, 2000; Strahan, 1995). The spatial organization adopted by female *M. fuscus* allows higher abundances of females to occupy the easement, as they demonstrated no territorial behaviour. This indicates that *M. fuscus* are utilizing all available habitat within the easement, and it is encouraging to see this species utilized 80% of the reference easement over the study. Provided that appropriate management is employed, *M. fuscus* may be able to reach higher densities within the area.

It is uncertain if the low captures of male *M. fuscus* throughout the study reflect a real sex bias in the population, that males show an avoidance response to the traps, or if males have a preference to other habitat factors. Other studies (e.g. Bubela et al., 1991; Bubela and Happold, 1993; Wallis et al., 1982), have not reported evidence of a sex bias in *M. fuscus* populations; however, with such limited data on male *M. fuscus* in the present study, no assumptions can be made with any accuracy about how males interact in the population. Breeding did occur each year of the study however, which suggests that there are a number of males in the current *M. fuscus* population.

Some individual *M. fuscus* readily crossed the service road at least once, suggesting that the road does not represent a barrier to movement for this species. Concerns have been expressed that *M. fuscus* is under serious threat of genetic isolation within Victoria (Greville, 1990); however, their capability to cross the service road in this study, shows that populations within the easement, at least, are not fragmented by the road and maybe shows their willingness to cross small unsuitable areas to reach optimal habitat. The range of *M. fuscus* movement additionally suggests that they can move long distances between captures, are a fairly mobile species, and can be good dispersers given that the habitat provides the necessary structural attributes. This is supported by *M. fuscus* being one of the first species to colonize the newly managed sites, and highlights that they have the potential to colonize other sections of the easement from a source population, if the easement vegetation is allowed to develop the resources needed by this species. In areas prone to high growing vegetation, rotational slashing would create a mosaic of habitat ages within the easement, add heterogeneity to the area, and most importantly, would allow the easement to support higher densities of *M. fuscus*, by providing core habitat for *M. fuscus* populations. This management technique would create neighbouring patches of habitat that would help to decrease isolation of *M. fuscus* populations, and may decrease the time between re-colonization and slashing, through maintaining source populations and areas of refuge for current populations during times of management. Rotational slashing would also keep fuel loads to safe levels, while still controlling high growing vegetation.

The lack of juvenile captures is encouraging in some sense, as it indicates that either this species is extremely trap-shy at the juvenile stage, or adult *M. fuscus* are colonizing the managed sites from other sections within the easement. This suggests that there are other populations of *M. fuscus* living within the easement that have not previously been detected by survey techniques. It also implies that juveniles from a known breeding population at the reference site, are dispersing into suitable habitat elsewhere. The mass slashing technique currently being used, where the whole length of the easement is cleared of vegetation, is most likely jeopardizing *M. fuscus* colonization efforts and restricting them to small pockets of unmanaged or recovering areas, due to removal of all resources elsewhere in the easement. This type of management technique needs to be reassessed and other, less destructive techniques employed, to ensure that core habitat is maintained for *M. fuscus* populations. Spot spraying or selective cutting of emergent trees may be all that is needed in naturally low growing communities. This management technique additionally, will not isolate populations of *M. fuscus* to small areas in the easement.

RECOMMENDATIONS FOR MANAGEMENT

Potential biodiversity values do exist for Australian power line easements, provided that some changes occur to the current management practices. There is a need to develop appropriate management regimes within Australia, to ensure that power line easements have minimum potential to fragment small mammal populations, by supplying functional, usable habitat for small mammals and other species. There is a need to understand the responses of small mammal species to the short rotation times of power line management within Australia, in an effort to develop more appropriate management regimes, which do not compromise biodiversity values or the supply of power. Recommendations to achieve this include the following:

1. Relaxation of Short Rotation Times: There is a need for longer rotation times between major management events. Vegetation under the transmission line needs to be assessed to determine if management is necessary or appropriate at a given time, rather than having pre-determined rotation times, especially in areas of naturally low-growing vegetation;
2. Reassessment of Current Mass Slashing Technique: Reassessment needs to occur of the current management practice where the entire easement is slashed at one time. Spot spraying or selective cutting may be all that is needed in some sections of the easement, especially in low-growing vegetation. Selective spot spraying or cutting of emergent shrubs, would reduce fuel heights, and reduce the need for slashing in the short term; and
3. Rotational Slashing: If sections of the easement require constant management due to high growing vegetation and cannot be managed through selective spot spraying or cutting, rotational slashing should be employed to create a mosaic of habitat ages within the easement. This would create a network of neighbouring habitat patches for wildlife and would add heterogeneity to the area.

This is part of a larger study that examines small mammal community changes within power line easements, in an effort to develop management regimes that enhance the potential biodiversity benefits of easements through forests, without compromising the safe supply of power. Many other questions and issues are raised by this study, which need to be addressed in the future, such as cost analysis of the proposed recommendations to see how viable these options are for power companies to implement, as well as further analysis of population dynamics and habitat use of the small mammals communities within these areas.

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REFERENCES

Andrews, A. 1990. Fragmentation of Habitat by Roads and Utility Corridors: A Review. Australian Zoologist, 26: 130–141.

Baker, J., L. Ross, and R.J. Whelan. 1998. Power line Easments Through Forests: A Case Study of Impacts on Avifauna. Pacific Conservation Biology, 4: 79–89.

Barnett, J.L., R.A. How, and W.F. Humphreys. 1978. The Use of Habitat Components by Small Mammals in Eastern Australia. Australian Journal of Ecology, 3: 277–285.

Bennett, A.F. 1993. Microhabitat Use by the Long-nosed Potoroo, *Ipotorous trdactylus*, and Other Small Mammals in Remnant Forest Vegetation of South-Western Victoria. Wildlife Research, 20: 267–285.

Brown, D. 1995. The Impact of Species Introduced to Control Tree Invasion On the Vegetation of an Electrical Utility Right-Of-Way. Canadian Journal of Botany, 73: 1217–1228.

Brunner, H., R.L. Wallis, and P.F. Voutier. 1997. Locating and Trapping Broad-toothed Rat (*Mastacomys fuscus Thomas*) at Powelltown. The Victorian Naturalist, 94: 207–210.

Bubela, T.M. and D.C.D. Happold. 1993. The Social Organisation and Mating System of an Australian Subalpine Rodent, the Broad-toothed Rat, *Mastacomys fuscus* Thomas. Wildlife Research, 20: 405–417.

Bubela, T.M., D.C.D. Happold, and L.S. Broome. 1991. Home Range Activity of the Broad-toothed Rat, *Mastacomys fuscus*, in Subapline Heathland. Wildlife Research, 18: 39–48.

Burnett, S.E. 1992. Effects of Rainforest Road on Movements of Small Mammals: Mechanisms and Implications. Wildlife Research, 19: 95–104.

Carron, P.L., D.C.D. Happold, and T.M. Bubela. 1990. Diet of Two Sympatric Australian Subapline Rodents, *Mastacomys fuscus* and *Rattus fuscipes*. Australian Wildlife Research, 17: 479–489.

Chasko, G.G. and G.E. Gates. 1982. Avian Habitat Suitability Along a Transmission Line Corridor in an Oak-Hickory Forest Region. Wildlife Monographs, 82: 1–41.

Dunstan, C.E. and B.J. Fox. 1996. The Effects of Fragmentation and Disturbance of Rainforest Ground-Dwelling Small Mammals on the Robertson Plataeu, New South Wales, Australian. Journal of Biogeography, 23: 187–201.

Fox, B.J. and M.D. Fox. 1984. Small-Mammal Recolonization of Open-Forest Following Sand Mining. Journal of Ecology, 9: 241–252.

Fox, B.J., J.E. Taylor, and P.T. Thompson. 2003. Experimental Manipulation of Habitat Structure: A Retrogressive of the Small Mammal Succession. Journal of Animal Ecology, 72: 927–940.

Goosem, M. 2000. Effects of Tropical Rainforest Roads on Small Mammals: Edge Changes Community Composition. Wildlife Research, 27: 151–163.

Goosem, M. and H. Marsh. 1997. Fragmentation of a Small Mammal Community by a Power line Corridor Through a Tropical Rainforest. Wildlife Research, 24: 613–629.

Goldingay, R.L. and R.J. Whelan. 1997. Power line Easements: Do They Promote Edge Effects in Eucalypt Forests For Small Mammals. Wildlife Research, 24: 737–744.

Green, K. 2003. Altitudinal and Temporal Differences in the Food of Foxes (*Vulpes vulpes*) at Alpine and Subapline Altitudes in the Snowy Mountains. Wildlife Research, 30: 245–253.

Green, K. 2002. Selective Predation on the Broad-toothed Rat, *Mastacomys fuscus* (Rodentia: Muridae), by the Introduced Red Fox *Vulpes vulpes* (Carnivora: Canidae), in the Snowy Mountains, Australia. Austral Ecology, 27: 353–359.

Green, K. and W.S. Osborne. 2003. The Distribution and Status of the Broad-toothed rat *Mastacomys fuscus* (Rodentia:Muridae) in New South Wales and the Australian Captial Territory. Australian Zoologist, 32(2): 229–237.

Greville, W. 1990. Genetic Variation in the Broad-toothed Rat, *Mastacomys fuscus*. Unpublished Honours Thesis, Australian National University.

Hanowski, J.M., G.J. Niemi, and J.G. Blake. 1993. Seasonal Abundance and Composition of Forest Bird Communities adjacent to a Right-Of-Way In Northern Forests USA. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-Of-Way Management. J.G. Doucet, C. Seguin, and M. Giguere, eds. Vice-présidence Environment, Hydro-Québec.

Hocking, G.J. and M.M. Driessen. 2000. Status and Conservation of the Rodents of Tasmaina. Wildlife Research, 27: 371–377.

Kozakiewicz, M. 1993. Habitat Isolation and Ecological Barriers: The Effect on Small Mammal Populations and Communities. Acta Theriologica, 38: 1–30.

Macreadie, J., R.L. Wallis, and R. Adams. 1998. A Small Mammal Community Living in a Power line Easement at Bunyip State Park, Victoria. The Victorian Naturalist, 115: 120–123.

Monamy, V. and B.J. Fox. 2000. Small Mammal Succession is Determined by Vegetation Density Rather Than Time Elapsed Since Disturbance. Austral Ecology, 25: 580–587.

Museum Victoria Australia. 2002. Victorian Mammals Website. http://www.museum.vic.gov.au/ Accessed August 2004. Last updated 2002.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The Effects of Roads on Populations of Small Mammals. Journal of Applied Ecology, 11: 51–59.

Parks Victoria. 1998. Bunyip State Park Management Plan. Parks Victoria Kew (October, 1998).

Seebeck, J.H. 1971. Distribution and Habitat of the Broad-toothed Rat *Mastacomys fuscus* Thomas (Rodentia: Muridae) in Victoria. The Victorian Naturalist, 88: 310–323.

Seebeck, J.H. and P. Menkhorst. 2000. Status and Conservation of the Rodents of Victoria. Wildlife Research, 27: 357–369.

Smallidge, P.J., D.J. Leopold, and C.M. Allen. 1996. Communitry Characteristics and Vegetation Management of the Karner Blue Butterfly *(Lycaeides melissa samuelis)* Habitats on Rights-Of-Way in East-Central New York, USA. Journal of Applied Ecology, 33: 1405–1419.

Smallidge, P.J., D.J. Leopold, and C.M. Allen. 1993. Management Concerns for the Response of the Blue Lupine Communities on Rights-Of-Way In East-Central New York, USA to Environmental Factors and Vegetation Management. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-Of-Way Management. J.G. Doucet, C. Seguin, and M. Giguere, eds. Vice-présidence Environment, Hydro-Québec.

Strahan, R. (ed). 1995. The Mammals of Australia. Reed Books, Chatswood, NSW.

Taylor, J.M. 1984. The Oxford Guide to Australian Mammals. Oxford University Press, Melbourne.

Wallis, R.L., H. Brunner, and P.W. Menkhorst. 1982. Victorian Field Studies on the Broad-toothed Rat (*Mastacomys fuscus* Thomas). The Victorian Naturalist, 99: 13–21.

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Vernal Pool Identification and Protection – Current and Future Permitting Implications

James Durand, Bryan Windmiller, and F. Paul Richards

Development plans in and around vernal pools are receiving increased scrutiny in the regulatory arena, especially in New England. Vernal pools provide essential ephemeral breeding habitat in the life cycles of many species of amphibians, reptiles and invertebrates (a number of which are state-listed rare species). The electric power industry nationwide should be aware of the potential future permitting implications and "standards of care" that may be required to receive authorization for projects sited near or affecting vernal pools. In states such as Massachusetts, vernal pools are regulated through the Wetlands Protection Act, Surface Water Quality Standards, and Rivers Protection Act, among others. The terrestrial non-breeding habitat surrounding the pools is also regulated through the Massachusetts Endangered Species Act and local wetland bylaws administered by municipal conservation commissions. Emerging vernal pool regulation at the federal level is noted in New England, where vernal pools are categorized as "special inland waters and wetlands." The paper is divided into five sections. The first discusses the ecology of vernal pools and some of the life histories of species using them. The second summarizes implementing laws, rules and regulations in place in various New England states and at the New England Corps of Engineers. The third section presents three of National Grid's recent siting studies (two substations and one sub-transmission line) affected by the nearby presence of vernal pools. The fourth section briefly summarizes field survey techniques to identify vernal pool habitat. Lastly, the authors suggest procedures to successfully recognize and protect these resources while siting and permitting new or expanded facilities.

Keywords: Vernal pools, siting studies, amphibians, reptiles, rare species, Massachusetts, wetlands, right-of-way

INTRODUCTION

The siting of electric transmission (69 kV or greater), sub-transmission (23 to 46 kV) and substation facilities involves consideration of a multitude of ecological, cultural, social and political factors. Most of us are familiar with various spreadsheets that are created by project teams to account for and weigh those site-specific factors affecting siting options. Usually high on any such list are ecological factors and habitats, principally wetlands and rare species. One would not attempt to site power lines or substations without a clear understanding of where such resources exist in the defined study area and whether project-related impacts can be avoided, minimized, and/or mitigated.

One specific type of wetland resource that has received increased regulatory scrutiny in recent years is the vernal pool. Massachusetts was the first among the New England states to define vernal pools and offer specific standards for work within or adjacent to them under the Massachusetts Wetlands Protection Act. Today, the approximately 30,000 identified vernal pools in Massachusetts are regulated through provisions, not only the State wetlands program, but State water quality standards, the Massachusetts Rivers Protection Act, numerous local wetlands by-laws, and the federal Clean Water Act. Other states in New England have followed suit with ever-changing programs designed to protect wildlife communities that are dependent upon vernal pools. Thus, in Massachusetts and in-

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Fig. 1. Vernal pool habitat within electric transmission right-of-way.

Fig. 2. Spotted Salamander (*Ambystoma maculatum*).

Fig. 3. Blue-Spotted Salamander (*Ambystoma laterale*).

creasingly elsewhere in New England and nationally, vernal pools have become a major factor/constraint in the siting and design of electric utility projects (Fig. 1).

VERNAL POOLS: A UNIQUE REGULATORY WETLAND CLASSIFICATION IN NEW ENGLAND

Vernal pools, in a regulatory sense, are unique among regulated wetland resources in the northeastern United States in that they are primarily defined and identified by their constituent fauna rather than their soil, vegetative, or hydrological characteristics. In Massachusetts, as elsewhere in New England, a regulatory vernal pool is defined primarily as a fish-less body of water that provides breeding or other critical habitat to specific amphibian, reptile, and invertebrate species and lacks a permanent outlet. In Massachusetts, where the process of vernal pool identification and regulation is more advanced than elsewhere in the region, vernal pools typically are identified through field observation of egg masses or other evidence that one or more of five species of "vernal pool obligate" amphibians bred in a particular wetland.[1]

Breeding by any of the "obligate" species, namely: the wood frog (*Rana sylvatica*), and four species of mole salamanders – the spotted salamander (*Ambystoma maculatum*) (Fig. 2), blue-spotted salamander (*Ambystoma laterale*) (Fig. 3), Jefferson salamander (*Ambystoma jeffersonianum*), and marbled salamander (*Ambystoma opacum*) – is presumed to be a valid indicator of the presence of vernal pool habitat, unless the site is shown to have of the following conditions: 1) self-sustaining fish populations, 2) a permanent outlet (i.e., perennial streams cannot contain vernal pool habitat, 3) and absence of surface water for at least two consecutive months during the spring or summer. Vernal pools may also be defined by the presence of breeding activity by fairy shrimp (Anostraca: *Eubranchipus* spp.), and other invertebrate, amphibian and reptile species defined as "facultative" vernal pool breeders that often breed in wetlands that do not qualify as vernal pools. Therefore, field personnel must understand the basic natural history of vernal pool-dependent animal species, particularly the obligate amphibians, and must conduct field surveys during the appropriate season to determine whether or not regulatory protections afforded vernal pools and the animal species that inhabit them are a constraint upon the intended development of a site.

A second attribute of vernal pools that exerts strong constraints on the siting of electric transmission facilities in their vicinity is the relatively high proba-

1 "Obligate" vernal pool species are those that were presumed to breed almost exclusively in fish-free bodies of water. In actuality, mole salamanders and, to a somewhat lesser degree, wood frogs, commonly breed in permanent water bodies with fish in many parts of New England, particularly hilly regions and along the eastern coast of Maine (B. Windmiller, pers. obs.).

bility of occurrence within them of state-listed rare animal species. Although several dozen State-listed vertebrate and invertebrate species in Massachusetts may be found in association with vernal pools, the bulk of vernal pool-associated rare species observations and thus the majority of vernal pool-associated regulatory conflicts involve the presence of rare salamanders (particularly: blue-spotted, Jefferson, marbled, and four-toed (*Hemidactylium scutatum*) salamanders) and turtles (particularly: spotted turtles (*Clemmys guttata*) and Blanding's turtles (*Emydoidea blandingii*)).

Since the presence of rare species greatly increases the regulatory constraints placed on development within or nearby (typically within 1,000 feet) vernal pools, it is also critical that electric utility companies carefully consider the possibility that any confirmed or potential vernal pools within 1,000 feet of a project may serve as rare species habitat. Determining if state-listed salamander and turtle species are present in vernal pools and, if so, evaluating the potential impacts of the proposed project upon rare species populations requires both knowledge of the natural history and habitat ecology of the rare amphibian and reptile species and familiarity with field methods best suited to locate, count, and, if necessary, track the movements of individual salamanders and turtles.

Life histories and movement patterns of vernal pool-associated amphibians and reptiles

Since most vernal pools dry up or dry down significantly during the late summer months, amphibians and reptiles that make use of vernal pools also depend upon other terrestrial and aquatic habitat types that may be hundreds or even thousands of feet away. Amphibians that lay their eggs in vernal pools usually occupy the pools only during their egg and larval stages, with adults spending the non-breeding months in other habitat types. The patterns of movement between vernal pool breeding sites and other non-breeding habitat areas vary greatly among the amphibian species of the northeastern United States.

The wood frog, the only "obligate" vernal pool-breeding anuran species, is among the first amphibian species active in the late winter or early spring. Wood frogs in eastern Massachusetts typically breed between mid-March and early April. Most individuals spend less than 2 weeks in their vernal pool breeding habitat and then disperse tens to hundred of yards into surrounding areas of forested wetlands where they characteristically spend the spring and summer months (Regosin et al., 2003b; R. Baldwin, in prep.). Many wood frogs, however, overwinter in forested uplands, often within 300 feet of their springtime breeding sites (Regosin et al., 2003b; B. Windmiller, unpubl. data). Wood frog tadpoles generally metamorphose and disperse into forested wetland areas in late June and July in Massachusetts. Wood frogs are short-lived; most adults only live to breed once during their lifetime and few live to be four years of age (Berven, 1990). Thus, wood frog populations are greatly dependent upon dispersal between populations, as a two or three-year long drought that causes vernal pools to dry before the tadpoles can metamorphose and disperse, may be sufficient to cause the local extinction of a sizeable but isolated population.

In contrast to wood frogs, the four species of mole salamanders (*Ambystoma* spp.) native to New England are relatively long-lived, primarily upland-dwelling animals. Spotted salamanders and salamanders of the blue-spotted – Jefferson salamander species complex (many New England populations are dominated by polyploid hybrids) all breed in water bodies in early spring, roughly synchronous with wood frogs. Marbled salamanders are unique in the genus in that they breed in autumn, depositing their eggs on moist soil that has been exposed by falling water levels of vernal pools and other suitable wetlands (Kaplan and Crump, 1978). The embryo and larval stages of *Ambystoma* salamanders are longer than those in wood frogs, so that larvae of the spring-breeding species commonly metamorphose in August throughout much of New England (4–5 months from breeding to metamorphosis) and Marbled salamander larvae typically metamorphose in June or July (8–10 months from breeding to metamorphosis). Mole salamanders thus generally require wetlands that maintain surface water for most of the year to successfully produce metamorphs and the largest populations are often associated with semi-permanent or even permanently-flooded wetlands (Windmiller, 1996).

Following breeding activities, adult mole salamanders disperse into surrounding forested habitat, as do newly-metamorphosed juveniles. Data from the analyses of growth rings in salamander toe bones have revealed at least one instance of a spotted salamander living to more than 30 years of age (Flageole and LeClair, 1992), many individuals live to 8 years or more of age. Mature mole salamanders will have spent more than 90% of their lives on land, usually in upland forest. Little is known about differences in non-breeding habitat selection among the species, though New England mole salamanders are known to inhabit forested areas with soils that range from hydric to xeric (Windmiller, 1996; Regosin, 2003a). Within their forested haunts, mole salamanders have most commonly been observed occupying small mammal burrows, particularly those of the Short-Tail Shrew, *Blarina brevicauda* (Windmiller, 1996; Madison, 1997). Several studies concluded that most mole salamanders in the studied populations inhabited forested uplands within 200 meters of their breeding sites, though some individuals may migrate upwards of 300–400 meters (Williams, 1973; Kleeburger and Werner, 1983; Regosin, 2003). Spring-breeding mole salamander species often move about their terrestrial habitat in the autumn months and, at least in colder areas of New England, may seek out deeper burrow systems, such as those created by *Peromyscus* mice species, as overwintering sites (Madison, 1997).

Spotted and blue-spotted salamander populations have been observed to decline following partial clearing of forested areas within 200 meters of their breeding sites (Homan, 2003). The slow-moving mole salamanders are also highly vulnerable to road kill from roads that separate terrestrial and aquatic breeding habitat, and may often avoid crossing large stretches of open ground (Windmiller, 1996). The relatively high annual survivorship rates of adult mole salamanders, which ensures that populations can weather periods of drought and low production of juveniles, may conversely enable populations of mole salamanders that are isolated by roads and urban landscapes to persist for many generations (J. Regosin and B. Windmiller, unpubl. data).

Freshwater turtle species primarily use vernal pools as rich feeding grounds when the pools are flooded. The turtles often occupy other, more permanently-flooded wetlands from late summer to early spring. All turtle species in the northeastern United States nest in terrestrial habitat, usually in sparsely-vegetated areas with fairly dry sands and gravels. Spotted and Blanding's turtles, the two rare species commonly-associated with vernal pool habitat in New England, often move between vernal pools and other wetlands in the course of the year (Rowe and Moll, 1991; Graham, 1995; Milam and Melvin, 2001). Blanding's turtles, the larger and more vagile of the two species, may move several kilometers in straight-line distance between vernal pools and upland nesting habitat or other wetlands (Rowe and Moll, 1991).

Both Blanding's and spotted turtles mature slowly, live for several decades (Ernst, 1976; Congdon and van Loben Sels, 1993), and lay relatively few eggs (Gibbons, 1968; Ernst, 1976), most of which succumb to predation (Butler and Graham, 1995). The most critical demographic factor in the conservation of rare turtle populations is therefore the high survivorship rates of adults that allow females many opportunities to breed over the course of their lifetimes. Mathematical models indicate that turtle populations may be sent into slow, inexorable decline by even slight increases in the mortality rates of adults (Congdon et al., 1993). Thus, given their habits of often moving fairly long distances between different habitat elements in the landscape, Blanding's and spotted turtle populations may be vulnerable to any increases in road or traffic density within their ranges of movement. Removal of adults by collectors or casual pet keepers may also be a substantial threat to populations (Garber, 1989).

REGULATORY PROTECTION OF VERNAL POOLS AND VERNAL POOL-ASSOCIATED RARE WILDLIFE SPECIES IN MASSACHUSETTS AND OTHER NEW ENGLAND STATES

The regulatory protection of vernal pools is still in its infancy through much of New England, however, some states are ahead of others in instituting mapping and inventory procedures, certification guidelines and protection of vernal pool habitat. The significance of vernal pool habitat is becoming increasingly recognized at the scientific and regulatory levels. Regulations have been developed to afford protection of vernal pool habitat. In Massachusetts for instance, regulation and protection of vernal pool habitat has been established at the State level, and administered at the local level with technical advisory support from the State Natural Heritage and Endangered Species Program. The importance of preserving vernal pool habitat is gaining increased recognition at the federal level as well, as demonstrated through the language found in the U.S. Army Corps of Engineers' Programmatic General Permits issued for each New England state.

Some states have established regulations for the protection of vernal pools including the actual breeding pool and the adjacent wetland habitat, which are summarized in the proceeding narrative. The regulation and protection of vernal pools in New England is expanding to encompass protection of populations of species with an emphasis on state-listed rare species. Massachusetts has established, through the Massachusetts Endangered Species Act and Wetlands Protection Act regulations, protection of State-listed vernal pool breeding species habitats, through mapping of "certified" vernal pools and "estimated habitats of rare wetland-dependent wildlife." These habitats not only encompass the breeding pool but may also include the adjacent upland non-breeding habitat utilized by these species with terrestrial habitats ranging from a distance of 100 feet to 1,000 feet from the pool.

Vernal pool-associated rare species protection in Massachusetts

As the science of vernal pool ecology advances so does the regulatory climate. In Massachusetts for example, a current trend is to expand protection of vernal pools to the terrestrial, non-breeding surrounding upland habitats, which commonly range from 500 to 1,000 feet from the vernal pool. The requirements for vernal pool buffer zone considerations in habitats of State-listed rare species is receiving increased scrutiny by the State and local regulatory agencies, and this is where the need to conduct intensive biological field surveys of the vernal pool and adjacent non-breeding, terrestrial habitat may come into play when performing siting, constraints analysis and feasibility studies for a new or expanded facility.

Vernal pools that provide breeding habitat to State-listed rare species benefit from the added layer of protection offered by State endangered species acts, as established by the Massachusetts Endangered Species Act (MESA). MESA prohibits the "taking" of any rare plant or animal species listed as endangered, threatened, or of special concern by the Massachusetts Division of Fisheries and Wildlife. The term "taking" in this context includes, but is not limited to, "disrupting the nesting, breeding, feeding, or migratory activity of an animal or plant." MESA is administered by the Massachusetts Natural Heritage and Endangered Species Program (MNHESP). The MNHESP is the lead State agency responsible for determining if a proposed project would cause an adverse effect on any State-listed rare species. The MNHESP makes a determination of the project's propensity to adversely affect the "capacity of a habitat to support a population of endangered or threatened species," including several obligate vernal pool-amphibian species: blue-spotted salamander, marbled salamander; Jefferson salamander; intricate fairy shrimp (*Eubranchipus intricatus*); and vernal pool-associated reptiles including spotted turtle and Blanding's turtle.

401 Water Quality Standards – Vernal pools may also be afforded additional protection under other State-established regulations. The Massachusetts Section 401 Water Quality Certification regulations designate "certified" vernal pools as Outstanding Resource Waters (ORWs), giving these waters a higher level of protection through the Surface Water Quality Standards anti-degradation provision prohibiting the alteration or filling of an ORW.

Federal jurisdiction of vernal pools

The U.S. Army Corps of Engineers, New England District revoked the Section 404 Nationwide Permits in the early 1990's and subsequently issued separate Programmatic General Permits (PGPs) to each of the six New England States. The Nationwide Permit Program provides an expedited review process for activities in waters of the United States, including wetlands, that result in no more than minimal individual and cumulative adverse effects on the aquatic environment.

In Massachusetts for example, the PGP was issued in 1995 without mention of vernal pools. When the Massachusetts PGP was reissued in 2000, it specifically identified vernal pools as special inland waters and wetlands. This revision to the PGP demonstrates the level of recognition that vernal pools have received as critical wildlife habitats. The Corps of Engineers current PGPs issued to Connecticut, Maine, Massachusetts, and Vermont specifically list vernal pools as resources requiring further review by the Corps. Activities with the potential to affect vernal pools are excluded from authorization under Category I Non-Reporting activity of the PGP.

Further evidence of the expanding jurisdictional review associated with vernal pools is Programmatic General Permit Condition number 24 of the Maine PGP, which states that "Impacts to uplands in proximity (within 500 feet) to the vernal pools referenced in Definitions of Categories shall be minimized to the maximum extent possible."

The New Hampshire PGP includes a clause which states that projects in Waters of the U.S. that function as vernal pools require reporting to and screening by the Corps and Federal resource agencies. The NH PGP also notes that the projects meeting the State definition of "Minimum Impacts Projects," which typically qualify under the non-reporting criteria of the NH PGP, do not apply to projects for work in Special Aquatic Sites or Waters of the U.S. that function as vernal pools. These projects must be reviewed through the screening procedures established under the NH PGP.

The Programmatic General Permit Conditions of the PGP issued to each of the New England States includes a requirement for addressing *Environmental Values*. This PGP condition states that "The permittee shall make every reasonable effort to carry out the construction or operation of the work authorized by the PGP in a manner so as to maintain, as much as practicable, and to minimize any adverse impacts on existing fish, wildlife, and natural environmental values." This condition could and often times is interpreted to include minimizing adverse effects on vernal pool species inhabiting regulated waters and wetlands of the U.S.

The impacts of the SWANCC decision (Solid Waste Agency of Northern Cook County vs. United States Army Corps of Engineers et al) on the Corps' jurisdiction and regulation of vernal pools is a topic that deserves its own separate discussion. Intrastate, isolated waters or wetlands that have no nexus to interstate commerce other than use by migratory birds generally may no longer be considered Corps' jurisdictional Waters of the U.S. These non-regulated areas can include isolated vernal pools. In these cases a jurisdictional determination on the issue of "adjacency" may be deemed appropriate. The term "adjacency" in relation to jurisdictional wetlands infers that "adjacent wetlands" are those bordering, contiguous, or neighboring other jurisdictional wetlands. A general rule of thumb that has been used, in part, in New England to determine if a wetland is neighboring is whether the wetland area in question is located within 500 feet of a jurisdictional wetland or water of the U.S. This 500-foot threshold is a biological and ecological element derived from an average ranking of home range/migration distances of wildlife species known to occur in New England wetlands. This wildlife species inventory includes some commonly recognized vernal pool species. Therefore, if isolated vernal pools can be demonstrated to provide similar ecological functions that create an interstate commerce connection, they may be determined to be federally jurisdictional.

State jurisdiction of vernal pools

Over the course of the past fifteen years, state wetland and water quality regulations have evolved to provide regulatory review and set minimum standards for projects potentially affecting vernal pool habitat. Massachusetts was the first State in New England to develop vernal pool regulations.

Massachusetts

On November 1, 1987 the Massachusetts Wetland Protection Act Regulations were revised to include provisions for the protection of certain vernal pool habitats within the Commonwealth of Massachusetts. Vernal pools that were afforded some level of protection were those that had been certified by the Massachusetts Natural Heritage and Endangered Species Program (MNHESP) and which were located within regulated wetland resource areas. In May 1988, the MNHESP developed the "Guidelines for Certification of Vernal Pool Habitat," which established the biological criteria required to document the presence of actual vernal pool habitat. In that same year, in coordination with the Massachusetts Audubon Society, the first edition of "A Citizen's Step By Step Guide to Protecting Venal Pools" was published providing professional and amateur naturalists instructions on how to proceed with identifying and certifying a vernal pool to be included in the State inventory. The MNHESP enacted a program whereby vernal pools can be Certified affording them protection under several state regulatory programs. As of the second quarter of 2004, the MNHESP certified 3,401 vernal pools in the Commonwealth.

In the spring of 2001, the MNESP issued the "Massachusetts Aerial Photo Survey of Potential Vernal Pools." This publication presented the first comprehensive aerial-photo survey and inventory of potential vernal pools in Massachusetts. This survey was undertaken to provide a statewide inventory of potential vernal pools (PVPs) that were interpreted from aerial photographs. PVPs were photo-interpreted from the use of 1:12,000 scale ($1'' = 1,000'$ on the ground) color infrared aerial photographs (Burne, 2001). These aerial photo-interpretations depict an overview of the number and spatial distribution of vernal pool habitats within the Commonwealth. The aerial survey includes an inventory of approximately 30,000 potential vernal pools throughout the Commonwealth with an admittance that there are likely more errors of omission than errors of commission.

Connecticut

The Connecticut Wetland and Watercourses Act affords jurisdiction to vernal pools if the pool is located within a State-regulated or federally regulated wetland. The Connecticut Inland Wetlands and Watercourses Act defines State regulated wetlands as "submerged lands consisting of soil types designated as poorly drained, very poorly drained, alluvial, and floodplain." Vernal pools meeting this soils criteria, whether they are adjacent or isolated wetlands, would thereby be regulated by the Connecticut Department of Environmental Protection and at the local level by the municipal inland wetland and watercourse agencies.

Maine

Vernal pools are regulated as freshwater wetlands by the Maine Natural Resources Protection Act (MNRPA). There are some inherent limitations to this protection of vernal pools, since the alteration of less than 4,300 square feet of a freshwater wetland may be exempt from permit requirements and pools encompassing less than 4,300 square feet may be in jeopardy of being altered. In an effort to initiate regulation of vernal pools, the MNRPA was revised to add vernal pools to the definition of "significant wildlife habitat." The provisions for allowing a closer environmental review of proposed alterations to vernal pools as significant wildlife habitat are established in the law but have not been implemented through rule making. In 1997 the Maine Audubon Society developed a non-regulatory vernal pool program to establish guidelines for identifying vernal pools and documenting the biological characteristics of vernal pools. The University of Maine, Department of Plant, Soil and Environmental Sciences; the Maine Audubon Society; and the Maine Department of Inland Fisheries and Wildlife (Calhoun et al., 2002) have corroborated on an intensive survey of vernal pools in the State of Maine. The purpose of the survey is to assess pool physical characteristics, landscape setting, and presence of pool-breeding amphibians to guide development of potential vernal pool conservation strategies.

New Hampshire

Vernal pools are regulated under the New Hampshire Wetlands Bureau Rules WT 100–700 only if the pools are located within other state or federally regulated wetlands. The identification and delineation of jurisdictional wetlands in New Hampshire is based on the 1987 Federal Manual for Identifying Jurisdictional Wetlands, and the Field Indicators for Identifying Hydric Soils in New England. Vernal pools that meet the definition of wetland or are located within a larger wetland complex are regulated as wetlands under the jurisdiction of the New Hampshire Department of Environmental Service Wetlands Bureau. Potential impacts to vernal pools would be viewed in a cumulative review of Minor or Major Impact Projects established under the State wetland rules. In an effort to establish an inventory for isolated vernal pools located with upland landscapes, the New Hampshire Fish and Game Department, Non-game and Endangered Wildlife Program developed a vernal pool documentation program to promote local conservation efforts of these types of vernal pools that may not otherwise receive protection.

Rhode Island
Vernal pools are regulated in Rhode Island as "special aquatic sites." The Rhode Island Freshwater Wetlands Act and Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act establish jurisdiction of freshwater wetlands (swamps, marshes, bogs, wet meadows, ponds), floodplains, perimeter wetlands and riverbank wetlands. In 1994 vernal pools were incorporated into a new regulatory category of "special aquatic site," which is defined as "a body of open standing water… which does not meet the definition of pond but which is capable of supporting and providing habitat for aquatic life forms." Additional protection may be given to vernal pools in Rhode Island through regulated setbacks established in the wetland regulations.

Vermont
The Vermont Wetland Rules do not include a direct reference to vernal pools. Vernal pools; however, can be considered as "wetlands significant for wildlife" through Rule 5.4: Function – Wildlife and Migratory Bird Habitat. If a wetland or vernal pool habitat possesses the characteristics of and is deemed significant for wildlife, then it is determined to be either a Class 1 or Class 2 wetland, and is therefore regulated by the Wetland Rules. The Vermont Department of Environmental Conservation and the Vermont Non-game and Natural Heritage Program have begun working collaboratively to develop methods for the classification and characterization of seasonal pools (vernal pools) to standardize methods in assessing and documenting vernal pools to enhance conservation and protection efforts of vernal pools in the State of Vermont. This effort includes the development of the June 2003 Vermont Bioassessment of Vernal Pools published by the Vermont Nongame and Natural Heritage Program.

Local jurisdiction of vernal pools

The regulation and protection of vernal pools are in some instances addressed at the local municipal level. Local conservation commissions may establish wetland bylaws and ordinances to provide specific protection of vernal pools. An example of this is the Town of Amherst, Massachusetts, where there is provision in their local wetland bylaw that establishes vernal pools as areas subject to regulation and protection whether the pools are certified vernal pools, potential vernal pools, or suspected vernal pool habitat. These local regulations also establish a minimum 100-foot protective buffer zone to vernal pools.

Regulatory implications for new projects

The permitting implications and permit conditions imposed on a project may ultimately be a reflection on the up-front approach used in the siting and site selection process of a new project. In Massachusetts in particular, vernal pool habitat is one of the routing constraints considered when siting a new or expanded utility corridor or in selecting a new substation site. The size, physiographic location, and stakeholder controversy over a project largely dictates the level of alternative analyses performed to identify a preferred corridor or site. In the authors' opinions, a thorough alternatives analysis combined with the completion of a constraints analysis and identification of potential fatal flaws should be strongly considered at the onset of project development. The efforts and costs expended up-front can avoid schedule delays and unforeseen costs at the back-end of a project. The authors' recent project experiences have involved conducting intensive biological surveys to identify the presence of vernal pool-rare species and to document their migration patterns and habitat utilization preferences. These types of field survey requirements can sometimes be unexpected, and the costs and time requirements to complete the surveys can be substantial. Identifying these survey needs and the seasonal limitations for performing species-specific surveys is critical to project planning.

The components of a project that have the potential to adversely effect a vernal pool or rare species may necessitate consideration of one or more of the following mitigation measures, as experience by National Grid with the projects presented in the following case studies:

- Redesign of proposed facility or reduction of project footprint;
- Relocation of pole structures and lengthening spans across critical resources;
- Conducting a pre-construction trap and removal program to relocate targeted species outside of the work corridor, and maintaining a wildlife barrier during construction;
- Habitat restoration or enhancement to maximize overall wildlife habitat diversity;
- Scheduling considerations based upon required construction windows and seasonal limitations, such as avoiding a spring migration period (i.e., March 1 to May 15);
- Conduct biological monitoring during construction activities; and
- Conservation efforts to include preserving open space; and funding for research studies such as metapopulation dynamics, ecology and distribution, and status and population trends.

RECENT NATIONAL GRID USA CASE STUDIES IN MASSACHUSETTS

In New England, the National Grid USA system encompasses electric high voltage transmission, subtransmission, and substation facilities in portions of four states (Massachusetts, Rhode Island, New Hampshire and Vermont). In Massachusetts, National Grid operates about 2,100 circuit miles of high voltage transmission lines and about 275 substations. Many tens of thousands of miles of roadside distribution lines (4 to 13 kV) are also part of the system but are not the focus of this paper.

As noted previously, the state with the most complex set of regulations involving vernal pools is Massachusetts. Roughly 3,400 certified vernal pools and 30,000 potential vernal pools exist in Massachusetts. The following describes several recent National Grid (formerly Massachusetts Electric Company and New England Power Company) projects in which vernal pools were major factors in siting and permitting. The case studies exhibit some of the range of regulatory issues that may arise in Massachusetts when vernal pools and vernal pool-associated rare species are located near proposed electric utility work.

Case I. Westford 57 substation – proposed work near previously known certified vernal pool and within 600 feet of previous record for state-listed rare species (blue-spotted salamander)

Setting

In the spring of 2000, Massachusetts Electric Company (MEC), a National Grid USA company, determined since the Town of Westford was growing at such a fast rate electrically, that a new tap of the 115 kV system in town was needed as quickly as possible. The company owned several properties in town adjacent to the high voltage lines. The most appropriate site given size, nearness to the load, and distribution factors all led to the conclusion that MEC's Concord Road site was best suited for the new proposed substation. There was a small electrical switching station already on the parcel.

MEC was aware that there was a certified vernal pool touching the eastern edge of the property. As a result, MEC had its wetland consultant conduct two reconnaissance surveys of the vernal pool in the spring of 2000. Blue-spotted salamanders, a Species of Special Concern in Massachusetts, were documented to occur in a mixed deciduous-coniferous upland forest located 600 feet to the east of the project site. No blue-spotted salamanders; however, had been documented on the site or within the adjacent vernal pool. It was unknown if blue-spotted salamanders used the vernal pool on the MEC property, therefore more extensive field study was conducted

During the spring and summer of 2000, studies were done at the site to document, flag and survey all ecological resources (i.e., wetlands, the certified vernal pool, an intermittent stream, tree lines, the fallow field upon which the substation was to be built, etc.). At the same time, aerials were flown of the site and artists renderings were prepared. Permitting (filing of a Notice of Intent) under the Massachusetts Wetlands Protection Act began before the local Conservation Commission. Concurrent with that filing, a copy of the Notice was sent, as required by regulation, to the Massachusetts Natural Heritage and Endangered Species Program (NHESP) office. NHESP responded that they had no significant interest in MEC's project as it was more than 100 feet from the edge of the wetland containing the certified vernal pool and also because the upland, fallow field site chosen for the substation did not include non-breeding habitat for the blue-spotted salamander. The original location of the substation had been sited in a fallow upland meadow and in a manner that avoided any clearing of trees that provided canopy cover to the vernal pool, thus not presumably in habitat used by forest-dwelling blue-spotted salamanders. The final revised design layout of the substation was similar to that of the original design with the exception of several modifications including: realignment of the substation footprint to maintain a contiguous buffer along the adjacent wetland; reduction in the overall size of the substation; and a more extensive landscaping plan calling for partial replanting of the open fallow field.

By written presumption under the Massachusetts Wetlands Protection Act regulations, the fact that NHESP did not believe our project to have an effect on the Species of Special Concern might have ended regulatory issues deriving from the presence of a vernal pool near the proposed substation. Three abutting land-owners; however, unhappy with the project and acting under the aegis of the local Westford Wetlands Bylaw, hired an attorney to challenge the project on the grounds of irreparable harm to the local blue-spotted salamander population and the nearby, certified vernal pool. The Conservation Commission allowed the legal challenge and had MEC conduct a herpetological study to determine: 1) whether blue-spotted salamanders utilized the vernal pool near the proposed substation, 2) whether blue-spotted salamanders or other vernal pool-dependent wildlife species would be harmed by the proposed substation. MEC hired Hyla Ecological Services (Hyla) to obtain the required State collecting permit and do the special study. The following is a summary of the methods, findings and implications of the study.

Sampling design and strategy

Prior to the 2001 field season, MEC discussed various sampling designs with its consulting herpetologists and wetland specialists. Hyla's herpetologists felt that it was fairly likely that blue-spotted salamanders would be found breeding at the vernal pool in question, but that the proposed substation construction posed no threat to blue-spotted salamanders since the construction was to be located in old field habitat that is seldom used by this species. Thus, MEC and its consultants decided that it was critical to gather detailed data on the number of blue-spotted salamanders, if any, using the site, and on the movement patterns and distribution of salamanders in their upland non-breeding habitat so that the potential impact of the proposed construction on the salamander population could be reasonably quantified.

Hyla and ENSR staff therefore installed 1,700 linear feet of terrestrial and aquatic drift fences pitfall and funnel traps arrayed at every 15 meters on either side of the fence. The fencing enclosed both the vernal pool and the entire adjacent upland field. Subdivision of the drift fence array allowed the calculation of the precise number of amphibians trapped entering or leaving the area of proposed construction. Additionally, the herpetologists installed a grid of 24 unbaited minnow traps in the vernal pool. Traps were checked daily from March 15 to April 27, 2001, yielding a total effort of 3,370 trap-nights at the drift fence and 530 trap-nights at the minnow trap grid. Blue-spotted salamanders were marked individually by toe-clipping so that the movements of individuals throughout the project site could be tracked.

Results

In total, 47 individual blue-spotted salamanders were captured (41 adults and 6 juveniles). Ninety-four percent of the 34 breeding females were captured entering or exiting the vernal pool from the woodlands off-site and opposite the vernal pool. Only six percent of the individual blue-spotted salamanders moved across the field in which the substation was proposed. These three individual salamanders each spent only one day on the margins of the proposed construction site. Additionally, the herpetologists found two other vernal pool-associated rare species not previously known from the area: the four-toed salamander and the Mystic Valley amphipod (*Crangonyx aberrans*, a small freshwater crustacean); both of these species were only observed, however, in aquatic habitat distant from areas of proposed construction.

Implications

The project received approval from the Massachusetts Natural Heritage Program and Endangered Species Program and was eventually permitted and constructed. The issue of blue-spotted salamander presence near the construction and the potential impacts of the construction upon the salamander population ultimately resulted in a one-year setback in the project schedule. In addition to the cost of the study and rare species related permitting, the loss in time cost several hundred thousand dollars due to re-engineering of the local distribution system to accommodate increased load during the extended project permitting period.

Case II. King street to mill street 23 kV line – certified and potential vernal pools

Setting

In early August, 2003 a letter was sent by MEC to the NHESP requesting information on certified vernal pool species and rare wetland species inhabiting NHESP-mapped habitat along an existing 23 kV corridor on which a second 23 kV circuit on wood poles was being proposed. The response letter was not received until early November listing seven species on the Massachusetts Division of Fisheries and Wildlife lists of rare animals and plants. Most of these species, specifically: blue-spotted salamander, four-toed salamander, Blanding's turtle, spotted turtle, and New England Bluet (*Enallagma laterale*, a damselfly), are commonly associated with vernal pools. In November it was too late to reconnoiter the right-of-way (ROW) for the actual occurrence of any of these species in areas where the second wood pole line would be constructed.

Habitat mapping

In anticipation of the upcoming wetland permitting hearings before the two local Conservation Commissions involved (the line traversed two towns), MEC decided to do a habitat assessment of the species of interest. MEC hired Hyla Ecological Services to conduct a habitat survey using Global Positioning System (GPS) technology to map vernal pools and "potential" breeding, overwintering, and foraging habitat along the ROW relative to the existing pole line and anticipated locations of the new poles.

Several letters, assessments, and revisions (relocated poles) circulated between the NHESP staff, MEC and the two Conservation Commissions. Four poles were deemed "critical" from a species perspective, namely blue-spotted salamanders and four-toed salamanders. A zone between four other poles was highlighted as a potential nesting site for rare turtles. Hyla worked with the Massachusetts Natural Heritage and Endangered Species Program to produce a conservation plan that was agreeable to MEC in the absence of specific locational data on rare species. Seasonal restrictions were placed on wood pole installation in the areas of the ROW presumed to be critical to rare species conservation. Additionally, the plan called for onsite environmental monitoring by herpetologists during construction in sensitive areas and for detailed spring-time mapping of actual breeding and nesting habitat used by the rare species of concern.

Decisions

The project was constructed in mid-summer 2004. Herpetologists from Hyla, supported by MEC, monitored construction and established barriers to avoid conflict with rare species nesting. Four-toed salamanders were found to nest in three of the four areas categorized as probable nesting habitat for that species by Hyla, and

Table 1. Species observed at the Woodchuck Hill vernal pool, 2002–2004

Species	Latin name	2002	2003	2004
Spotted Salamander	*Ambystoma maculatum*	31 adult, 16 egg masses	16 egg masses	19 egg masses
Wood Frog	*Rana sylvatica*	137+ adults, 62 egg masses	61 egg masses	51 egg masses
Spring Peeper	*Pseudacris crucifer*	×	✓	✓
Isopod	*Caecidotea communis*	✓	✓	✓
Caddisfly larvae	*Limnephilidae* spp.	✓	✓	✓
Predaceoous Diving Beetle larvae	*Dytiscisae* spp.	✓	✓	✓
Crawling Water Beetle (adult)	*Haloplidae* spp.	✓	×	×
Alderfly larvae	*Megaloptera* spp.	✓	×	×
Mosquito larvae	*Culicidae* spp.	✓	✓	✓
Segmented Worm	*Lumbricidae* spp.	✓	✓	✓
pH of Vernal Pool		4.7	4.3	6.4
Dimensions of Vernal Pool		Approx. 100′ × 70′	Approx. 100′ × 70′	Approx. 100′ × 70′
Maximum Depth in Inches (Estimated Mean)		16 (8)	26 (12)	28 (12)

Notes: No adult live trapping conducted in 2003 or 2004.
✓: Species present.
×: Species not observed

equipment was successfully routed around nest sites. Only one Blanding's turtle was found at the site; no rare turtles were observed nesting on the ROW.

Implications

The implications of the late season start for rare species habitat assessment caused a two month delay in the project, which was scheduled to go on-line on June 1, in anticipation of the summer peak loads that the project was to serve. Fortunately, the peak demand was not realized during the extended construction period, which would have exposed the potential seriousness of the construction delay. The delay also necessitated the need to have a herpetologist on-site to perform morning reconnaissance surveys prior to construction to document and protect turtle nesting sites.

Case III. Woodchuck Hill substation – potential vernal pool

Setting

The Woodchuck Hill site is a 20-acre parcel owned by New England Power adjacent to a 115 kV corridor in North Andover, MA. System studies revealed rapid regional growth and the need for more electric power. In 2002 a Notice of Intent under the Massachusetts Wetlands Protection Act and the North Andover (MA) Wetlands Protection Bylaw was filed to site and construct a new 115 kV substation. There was a non-certified vernal pool onsite. New England Power decided to initiate an inventory of the pool's herpetological population for inclusion with the Notice. The Commission approved an Order of Conditions under which the project could be constructed. Condition 54 stipulated vernal pool monitoring.

Results

The results of the pre-construction (2002), construction (2003), and post-construction (2004) monitoring are presented in Table 1. The investigation concluded that there appeared to be no measurable deleterious impact to the vernal pool. Most of the forested upland onsite was left intact and construction/erosion control barriers precluded construction activity from affecting the vernal pool and its surrounding buffer. It should be noted that no adult spotted salamanders or wood frogs were captured in 2003 or 2004 because no live trapping was specifically done in those years. Trapping was done in 2002 to determine the presence or absence of blue-spotted salamanders, a Massachusetts-protected species. No blue-spotted salamanders were captured in 2002 so trapping was discontinued thereafter.

Implications

At the Woodchuck Hill site, a non-certified vernal pool was ordered by the local conservation commission to receive the same biological survey protocol and protections provided to one for which obligate or rare species were encountered, documented, and ultimately certified. Several years of post-construction monitoring were required, which increased project cost and precluded filing for a Certificate of Compliance to close out the project with the local conservation commission.

FIELD SURVEY TECHNIQUES FOR IDENTIFYING VERNAL POOL AND ASSOCIATED RARE SPECIES CONSTRAINTS ON ELECTRIC UTILITY PROJECTS

In Massachusetts, preliminary data on the potential presence of vernal pools and vernal pool-associated rare wildlife species can be garnered through GIS analysis of public data provided by MASSGIS. Specifically, data layers showing "Potential Vernal Pools," "Certified Vernal Pools," and areas of "Estimated" and "Priority Habitat" for State-listed rare species are available on the MASSGIS web site (http://www.mass.gov/mgis/). In practice, however, fewer than 10% of all vernal pools in Massachusetts have been identified and "Certified" and the list of "Potential Vernal Pools" contains many areas that do not meet vernal pool regulatory criteria and misses many that do. Similarly, the considerable majority of localities for state-listed vernal pool wildlife are still probably absent from the Massachusetts Division of Fisheries and Wildlife database. Thus, determining whether or not a specific utility project might be constrained by vernal pool and/or rare species-related regulations will generally require field surveys in addition to the review of public or privately obtained remote-sensing data (e.g. aerial photography, orthophotos, and GIS coverages).

Survey techniques for determining the presence or absence of vernal pool habitat

If a body of standing water, including wide spots and impoundments in intermittent stream systems, occurs in the project vicinity, it must be considered a possible vernal pool. The most efficient method for determining whether or not the water body is actually a vernal pool is to search for egg masses of the spring-breeding obligate amphibian species (wood frogs and mole salamanders). Egg mass searches, to be definitive, should be conducted at least twice during the appropriate seasonal window, and generally require wading through potential vernal pools. Although large numbers of egg masses are usually readily detected, small numbers can easily be missed due to dense vegetation or inexperience on the part of the observers.

Faunal indicators of vernal pool presence may also be sought throughout most of the year by searching for amphibian and aquatic invertebrate larvae and even by searching through the sediment in dried pool basins searching for the shells of fingernail clams (*Sphaeriidae*) and aquatic pulmonate snails (*Basommatophora*) and for the cases of caddisfly larvae (*Trichoptera*).

If a project cannot avoid impacts to soils or vegetation within 100 feet of a vernal pool, it may be useful to gather additional data on relative or absolute breeding sizes of obligate amphibian populations. Population size data may be useful in ranking the relative ecological importance of the vernal pool in question to obligate amphibian populations and may also serve as a baseline to determine whether the contemplated project has caused any reduction in amphibian population numbers. Indices of breeding population size may be gathered for wood frogs, spotted salamanders, and, somewhat less readily, for blue-spotted and Jefferson salamanders, by conducting thorough egg mass counts. Rigorous standardization of efforts and techniques should be used to compare egg mass counts between sites.

Fig. 4. Submerged minnow trap and drift fence array.

Fig. 5. Pre-construction exclusion fencing and pitfall trap array.

Trapping adult mole salamanders of the spring-breeding species through the use of unbaited minnow traps may also give comparative catch-per-unit-effort data useful in ranking the relative importance of vernal pools to obligate amphibian species; this is the most effective and efficient technique to use for detecting the presence/absence of blue-spotted and Jefferson salamanders, whose egg masses are often absent or undetectable in vernal pools in which breeding adults may be captured (Fig. 4). If accurate estimations of absolute breeding population size are required, pond-encircling drift fences with pitfall traps, coupled with marking captured amphibians, provides the best, though extremely labor-intensive and expensive technique (Fig. 5). If the results of the study of amphibian breeding population size is to be used as a baseline measure to evaluate future impacts of proposed construction, it is critically important to ensure that identical survey techniques can be employed during both the pre- and post-construction phases and, more so, that as many years of pre-construction data be gathered as possible given the large natural between-year variability in amphibian breeding effort.

Survey techniques for evaluating potential impacts on rare salamander and turtle populations

Electric utility companies proposing work within the vicinity (600–1,000 feet) of a vernal pool, may find themselves choosing to or forced to conduct surveys for the presence of rare vernal pool-associated amphibian or reptile species. Rare species surveys are likely to be required by regulators if state-listed amphibians or reptile are known or strongly suspected to occur in the area. Additionally, the project proponent may sometimes conclude that the risks of creating a self-inflicted problem by finding hitherto unknown rare species populations is outweighed by the risk of project opponents or regulators discovering the presence of rare species populations late in the permitting process (see discussion of Westford 57 case study, above).

In Massachusetts and elsewhere in New England, rare species regulatory authorities are likely to provide input into a protocol for adequately surveying an area for the presence of rare vernal pool wildlife. For salamanders, visual egg mass surveys or searches for nesting marbled salamanders are best coupled with minnow trap surveys for adult blue-spotted and Jefferson salamanders or larval marbled salamanders. Night-time dip-net surveys are also effective for detecting the presence of marbled salamander larvae. Drift fence surveys are rarely required for simply detecting the presence of rare species.

Surveys for spotted and Blanding's turtles most often combine visual searches for basking turtles, which are best conducted soon after the turtles first become active in the spring, with trapping surveys. Blanding's turtles are effectively captured in hoop traps baited with sardines or meat. Spotted turtles are often captured in baited hoop traps, but visual surveys in early spring and interception-type traps generally are more effective in the experience of one of the authors (BW).

If rare vernal pool associated amphibians and reptiles are present in a project area, regulatory authorities may require the collection of additional data on the movement patterns, population size, and habitat use of rare species populations that may be affected by the proposed project. Adult *Ambystoma* salamanders can be tracked using radio-telemetry, though such studies are few in number. Data on the radial distribution of salamanders in non-breeding habitat surrounding a vernal pool may also be gathered through circular statistical analysis of data on the number of individuals captured in mapped pitfall traps along a pond-encircling drift fence. Multiple arrays of drift fence can also be used to deduce salamander distribution patterns in non-breeding habitat.

Habitat use and movement patterns studies of Blanding's and spotted turtle populations usually are conducted by capturing a sufficient sample of individuals and attaching radio-transmitters to their carapaces. Since determining the location of nesting sites is often key to conserving turtle populations, it is critical that a sufficient sample of mature females is tracked. Additionally, many turtles overwinter in wetlands far from their spring or summer haunts and thus radio-telemetry studies of turtles for the purpose of evaluating project impacts should generally continue until the onset of hibernation in the autumn. Blanding's and spotted turtle populations may show substantial between-year shifts in habitat use patterns, thus multi-year studies are preferable when feasible. Keep in mind that since electrical facility expansion studies are usually load driven, there usually is not the luxury available for multi-year studies. Early coordination with regulators is therefore critical.

RECOMMENDATIONS FOR FUTURE PROJECTS

As can be seen from the examples, the common theme of the projects was that vernal pools and associated rare species are elements in the landscape, which must be factored into siting and permitting processes. Constraints analysis, route selection, and feasibility studies should incorporate mapping of vernal pool habitat with consideration given to the potential occurrence of non-wetland habitat and its adjacency to vernal pools. The potentially complicated dual understanding of vernal pool ecology and carefully sited/constructed electric power delivery infrastructure causes permitting to be uncertain and depends on the education of the regulatory audience in these matters.

Based on vernal pool ecology, evolving regulation, and National Grid's recent experience in Massachusetts, the co-authors of this paper offer the following recommendations:

- Starting Early—Time is a limiting factor in many cases to actively site and permit a project if vernal pools are at issue. Consider that obligate species utilization of vernal pools, especially if inhabited by rare species, is seasonal. Windows of opportunity for field surveys are critical and the seasonality aspect may impose delay or conversely provide for construction opportunities;
- Siting—For complex or potentially controversial projects a siting/due diligence study should be performed in the early stages of the planning process to identify any fatal flaw or potential impediment to siting and/or construction within a study area. This could include desktop mapping of suspected vernal pool habitats and field reconnaissance to ground-truth possible site/corridor limitations;
- Avoidance—If at all possible, avoid vernal pools and maintain a significant buffer around them. Remember that vernal pools are seasonal habitat; the species of interest live somewhere else most of the year.

Fig. 6. Captured Spotted Salamanders in pitfall trap.

Prudent avoidance of vernal pools and surrounding lands will strengthen your position come permitting time. An adequate evaluation of a preferred and alternative routes/sites may allow the flexibility to incorporate a route change to avoid a critical habitat;

- Scientific Studies—Engage well-recognized and knowledgeable wildlife biologists, preferably herpetologists, for potentially contentious projects. Since the science is evolving, it behooves you to get the best data/experts possible. You might not always hear what you want, but upfront, informed decisions can minimize exposure to risks at the backend of a project (Fig. 6);
- Buffers/Setbacks—If avoidance is not possible, do the utmost to buffer construction activity from the vernal pool. Maximize span lengths over, or directionally drill under, if necessary, to avoid direct impact. Make buffers as large as possible; and
- Mitigation—Since the science and success of current wetland mitigation efforts are open to debate, the assurance of vernal pool restoration/replication/creation is even more uncertain. Habitat preservation, or one-for-one protection of other nearby vernal pools and buffers should be explored.

REFERENCES

Berven, K.A. 1990. Factors affecting population fluctuations in larval and adult stages of the wood frog (*Rana sylvatica*). Ecology 71: (1599–1608).

Burkholder, R., C. Feral, F. Clark, and B. Windmiller. 1988. Certified – A Citizen's Step-by-Step Guide to Protecting Vernal Pools. Center for Public Service, Tufts University, for the Massachusetts Audubon Society.

Butler, B.O. and T.E. Graham. 1995. Early post-emergent behavior and habitat selection in hatchling Blanding's turtles, *Emydoidea blandingii*, in Massachusetts. Chelonian Cons. Biol. 1(3): 187–196.

Burne, M.R. 2001. Massachusetts Aerial Photo Survey of Potential Vernal Pools. Massachusetts Division of Fisheries and Wildlife, Natural Heritage and Endangered Species Program.

Calhoun, A.J.K., T.E. Walls, S.S. Stockwell, and M. McCollough. 2002. Evaluating Vernal Pools as a Basis for Conservation Strategies: A Maine Case Study. Wetlands Journal. 23(1): 70–81.

Congdon, J.D. and R.C. van Loben Sels. 1993. Relationships of reproductive traits and body size with attainment of sexual maturity and age in Blanding's turtles (*Emydoidea blandingii*). J. Evol. Biol. 6: 317–327.

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology 7(4): 826–833.

Ernst, C.H. 1976. Ecology of the spotted turtle, *Clemmys guttata* (Reptilia: Testudines, Testudinae), in southeastern Pennsylvania. J. Herpetol. 10(1): 25–33.

Flageole, S. and R. LeClair Jr. 1992. Étude démographique d'une population des salamanders (*Ambystoma maculatum*) l'aide de la méthode squeleto-chronologique. Can. J. Zool. 70: 740–749.

Garber, S.D. 1989. A comparison of two populations of *Clemmys insculpta*, the North American wood turtle. Plastron Papers 19: 32–35.

Gibbons, J.W. 1968. Observations on the ecology and population dynamics of the Blanding's turtle, *Emydoidea blandingii*. Can. J. Zool. 46: 288–290.

Graham, T.E. 1995. Habitat use and population parameters of the spotted turtle, *Clemmys guttata*, a Species of Special Concern in Massachusetts. Chelonian Cons. Biol. 1(3): 207–214.

Heinz, C.E. and S. Egan. 2001. Rhode Island Vernal Pools, http//www.uri.edu/cels/nrs/patron/. University of Rhode Island, Department of Natural Resource Science.

Homan, R.N. 2003. Conservation Studies of Amphibian Health at Individual, Population, and Landscape Scales. Ph.D. dissertation. Tufts Univ., Medford, MA.

Kaplan, R.H. and M.L. Crump. 1978. The non-cost of brooding in *Ambystoma opacum*. Copeia 1978 (1): 99–103.

Kenney, L.P. and M.R. Burne. 2000. A Field Guide to the Animals of Vernal Pools. Massachusetts Division of Fisheries and Wildlife, Natural Heritage and Endangered Species Program.

Kleeburger, S.R. and J.J. Werner. 1983. Post-breeding migration and summer movement of *Ambystoma maculatum*. J. Herpetol. 17(2): 176–177.

Klemens, M.W. 1993. Amphibians and Reptiles of Connecticut and Adjacent Regions. State Geological and Natural History Survey of Connecticut, Bulletin 112, Connecticut Department of Environmental Protection.

Madison, D.M. 1997. The emigration of radio-implanted spotted salamanders, *Ambystoma maculatum*, J. Herp. 31: 542–552.

Milam, J.C. and S.M. Melvin. 2001. Density, habitat use, movements, and conservation of spotted turtles (*Clemmys guttata*) in Massachusetts. J. Herpetol. 35: 418–427.

Oxbow Associates. 2004. Vernal Pool Post-Construction Habitat Review, Foster Street Electrical Substation, 2004 Field Season. Prepared for New England Power Company, Northborough, MA. Prepared by Oxbow Associates, Inc., Acton, MA.

Regosin, J.V. 2003. Terrestrial Habitat Use by Pool-Breeding Amphibians in a Suburban Landscape. Ph.D. dissertation, Tufts Univ., Medford, MA.

Regosin, J.V., B.S. Windmiller, and J.M. Reed. 2003a. Influence of abundance of small-mammal burrows and conspecifics on the density and distribution of spotted salamanders (*Ambystoma maculatum*) in terrestrial habitats. Can. J. Zool. 81: 596–605.

Regosin, J.V., B.S. Windmiller, and J.M. Reed. 2003b. Terrestrial habitat use and winter densities of the wood frog (*Rana sylvatica*) J. Herp. 37(2): 390–394.

Rowe, J.W. and E.O. Moll. 1991. A radiotelemetric study of activity and movements of the Blanding's turtle (*Emydoidea blandingii*) in northeastern Illinois. J. Herp. 25(2): 178–185.

Williams, P.K. 1973. Seasonal Movements and Population Dynamics of Four Sympatric Mole Salamanders, genus *Ambystoma*. Ph.D. dissertation. Indiana Univ., Bloomington, IN.

Windmiller, B.S. 1996. The Pond, the Forest, and the City: Spotted Salamander Ecology and Conservation in a Human-Dominated Landscape. Ph.D. dissertation. Tufts Univ., Medford, MA.

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Pipeline Construction and Compliance with the Migratory Bird Convention Act

Albert Lees, Shawn Duncan, and Tom Hanthorn

The Migratory Bird Convention Act (MBCA) and Regulations were enacted to implement in Canada the Migratory Bird Convention of 1916. The purpose of the Act and its enabling Regulation is to protect migratory birds and nests. Pertinent sections of the legislation prohibit: "... the killing, injure or harassment of a migratory bird; the disturbance, destruction or take of a nest, egg, or nest shelter of a migratory bird ..." There are no provisions within the MBCA or Regulations to allow for the incidental take of migratory birds in relation to projects undertaken within bird habitat. Generally, pipeline construction activities are planned to occur in accepted "windows" to avoid potential impacts to other natural resources or land use activities. Breeding and nesting activity generally occurs between April and August. These dates are regionally influenced and activity can start much earlier and extend later into the summer season. Given the long period for breeding and nesting activity, the available period to carry-out pipeline construction is being "squeezed" in between the end of the migratory bird breeding/nesting activity and the beginning of fall timing windows for fisheries and agricultural resources. The scope of most pipeline activities does not fit within this available time. This paper outlines how Maritimes & Northeast Pipeline LLP developed and implemented a program for managing compliance with the MBCA and Regulations during construction of the Saint John Lateral, in New Brunswick, Canada.

Keywords: Pipeline construction, migratory birds, compliance, mitigation, right-of-way

INTRODUCTION

The Maritimes and Northeast Pipeline (M&NP) transports natural gas from offshore Nova Scotia, through a 568 km mainline pipeline that starts in Goldboro NS and interconnects with the US Maritimes & Northeast Pipeline at St Stephen New Brunswick, Canada. The 110 km long Saint John Lateral ties-in to the M&NP mainline at approximately Kp 518.7 of the M&NP mainline and provides natural gas to the City of Saint John, NB (Fig. 1). The Saint John Lateral is a National Energy Board (NEB) regulated pipeline and was constructed in 2000. Approval to build and operate the Saint John Lateral was granted by NEB under authority of Certificate of Public Convenience and Necessity GC 102.

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

In granting the approval to build and operate the Saint John Lateral, the NEB issued a number of conditions one of which dealt with construction outside the preferred window (i.e. non-breeding period) for Migratory Birds. The specific condition stated was the following:

> "Unless the Board otherwise directs, all clearing of trees and other vegetation shall be undertaken during the preferred construction windows for protection of migratory birds as established by Environment Canada – Canadian Wildlife Service, the New Brunswick Department of Environment and the New Brunswick Department of Natural Resources and Energy (NBDNRE). If clearing is to be undertaken outside of the preferred window, M&NP shall consult with the above noted agencies and file with the Board for approval results of its consultation. This filing should include any agency concerns, comments and recommended mitigation."

The preferred window of construction to protect Migratory birds is generally from August 1 to March 31,

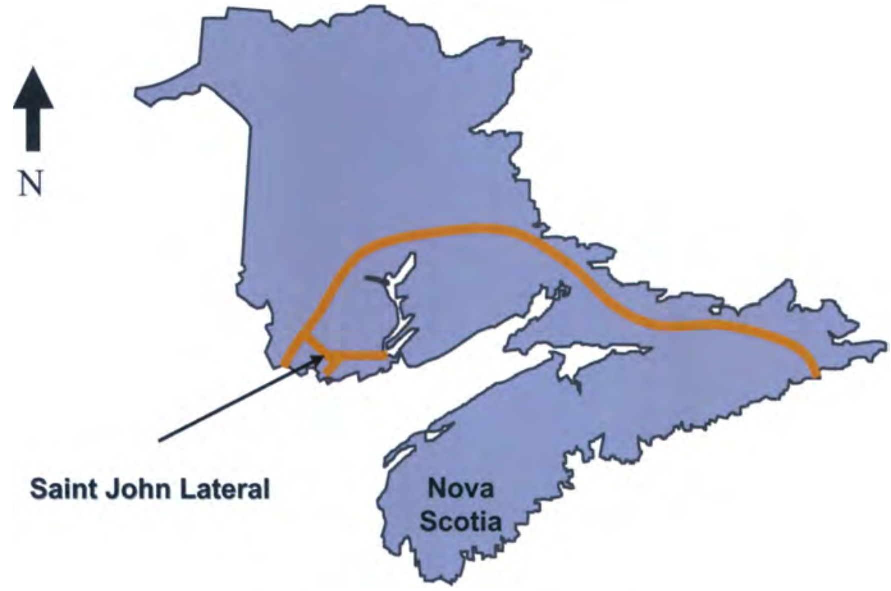

Fig. 1. Location of the Saint John Lateral.

prior to the start of the breeding season for Migratory birds.

Clearing commenced on about March 1, 2000 after all conditions of approval had been met and all necessary land easements were obtained for the project. On March 14, 2000 clearing was suspended due to unresolved issues associated with local labor unions. As a consequence, M&NP began to put in place a contingency plan to address clearing of the right-of-way (ROW) during the sensitive migratory bird-nesting season.

MIGRATORY BIRD LEGISLATION AND PIPELINE CONSTRUCTION

The Convention is an Empire Treaty whose purpose is to ensure the preservation of birds. It does not make explicit reference to economic activity in bird habitats other than activities should not lead to the take of migratory birds or their nests. The Migratory Bird Convention Act (MBCA) and Regulations were enacted to implement in Canada, the Migratory Bird Convention of 1916. The purpose of the Act and its enabling Regulation is to protect migratory birds and nests. Sections 5 & 6 of the Migratory bird regulations prohibit the following:

- Section 5. "... no person shall hunt (kill, injure, harass) a migratory bird ..."
- Section 6. "... no person shall disturb, destroy or take a nest, egg, nest shelter ... of a migratory bird ..."

There are other prohibitions within the regulations as well as the Migratory Bird Sanctuary Regulations that provide further protection to migratory birds. From an on-shore pipeline perspective; however, Sections 5 & 6 of the regulations are key. It is readily apparent that there are numerous pathways in which pipeline construction can interact with migratory birds from destruction of nests, loss of individual birds, and sensory disturbance to nesting birds and birds themselves. There are no pieces of legislation in Canada that allow incidental take of migratory birds.

From a pipeline perspective, adherence to timing windows to avoid impacts to various resources is a normal part of pipeline construction planning and mitigation. Due to the diversity of species, there is no one time that is optimal for all species due to variations between species (700+ in Canada), regional variation and climatic influences. Consequently, pipeline activities are being squeezed between late summer and fall when other land-use restrictions apply (Fig. 2).

MIGRATORY BIRD CONTINGENCY PLAN

The contingency plan to protect migratory birds during clearing and construction activities within the breeding/nesting period for migratory birds consisted of three components, as follows:

- Consultation with Canadian Wildlife Service (CWS); New Brunswick Department of Natural Resources and Energy (NBDRNE); and New Brunswick Department of Environment and Local Government (NBDELG);
- Migratory Bird Nesting Deterrent Program; and
- Migratory Bird Protection Program.

Consultation program

Paramount to the contingency plan was getting buy-in from CWS, NBDRNE, and NBDELG before any clearing activities could be resumed. The majority of the consultation was held with the CWS, while

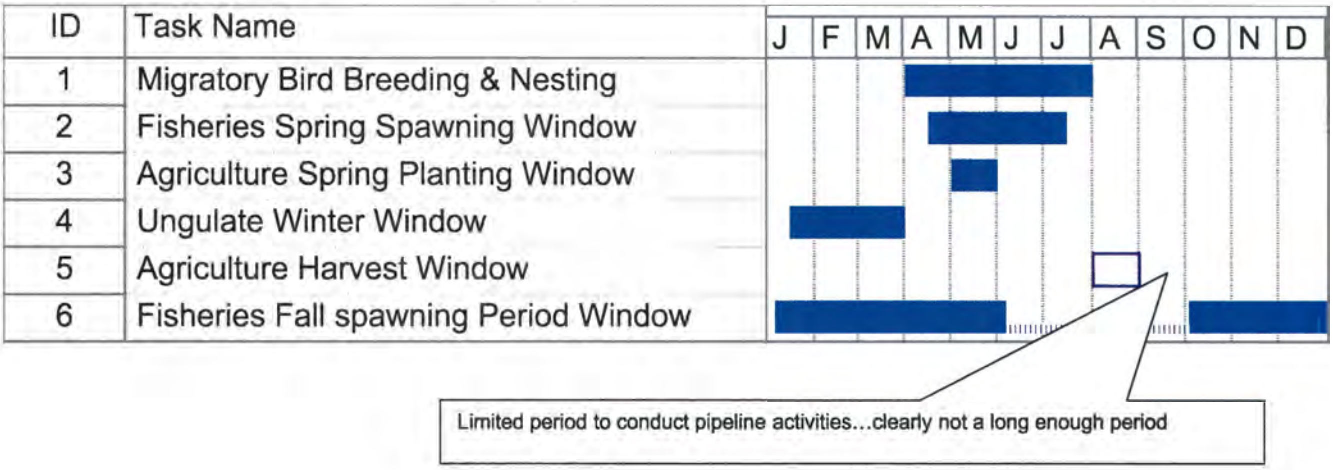

Fig. 2. Schematic of timing restrictions.

NBDRNE and NBDELG were kept informed of discussions and progress with the CWS. Initial meetings were held with CWS to discuss potential options with respect to continuing with clearing within the migratory nesting/breeding window. These initial meetings were used to build the contingency plan if clearing was to proceed outside the preferred window. During these meetings a number of options were explored, including bird nesting deterrent program, pre-clearing surveys, buffer around active nests, rare vs. common species, bird nest discovery protocols, and nest site monitoring. A chronology of the consultation program was documented along with issues and concerns, to be submitted to the NEB as required in permit conditions.

Migratory bird nesting deterrent program

M&NP anticipated that the consultation process would take a number of weeks before a decision could be reached on whether clearing would proceed outside the preferred window. Consequently, a bird nesting deterrent program was developed and implemented for the Saint John Lateral. Initially the program proposed involved people walking the ROW and using air horns to create a physical and sensory disturbance to discourage migratory bird nesting along the ROW. During the consultation program with CWS; however, the program was modified to exclude the use of air horns. It was felt that air horns could have a larger zone of influence and potentially sterilize an area greater with than M&NP's easement. The pipeline was divided into 10 routes ranging from 8–12 km each. The length of each route was dictated by access restrictions, such as rivers that could not be crossed, and the limited number of access roads in some areas. Teams of two workers covered most routes. Crews made noise by talking loudly, using homemade noisemakers and/or whistles. The deterrent program was implemented just after clearing was halted and continued until early July, when clearing of the pipeline was completed.

Migratory bird protection program

This program consisted of breeding bird surveys conducted at 10 intervals, pre-clearing surveys, and nest monitoring. In addition a migratory bird nest discovery protocol and rare species breeding bird summary list and associated buffers were developed and adhered to.

Breeding bird surveys

Critical to the success of the contingency plan was to conduct breeding bird surveys every 10 days to identify active nest sites or sites where there were indications of breeding/nesting activity. Experienced biologists were employed to carry out the weekly breeding bird surveys. If a nest site was observed or bird activity indicated that a nest may be nearby, the nest or area was marked with environmental flagging and depending on the species a buffer zone was flagged off to identify the area as a "no go" zone for clearing (Fig. 3). Buffers zones ranged in size from 10 m to 100 or more meters depending on the species. Generally, more sensitive, rare or endangered species had the more restrictive buffers.

Pre-clearing surveys

Pre-clearing nesting surveys were to be conducted no later than five days in advance of any of the clearing crews. This was to ensure no new nests had been established between the time of the breeding bird surveys and the time of clearing activities. Biologists experienced in bird identification conducted these surveys.

Bird nest monitoring

In order to complete the clearing of the Saint John Lateral it was necessary to monitor any identified nests until the bird had fledged at which time clearing of the buffer and nest site could be conducted. Once a nest was identified and the species determined, an estimate of when the birds would fledge was made. This information was put into a data base and used to determine

Fig. 3. Example of migratory bird nest and established buffer.

when clearing crews could potentially clear a nest site. Identified nests were checked on a regular basis and as soon as the young birds had fledged, the clearing crew cleared the site.

Migratory bird nest discovery protocol
Although the focus of the contingency plan was geared towards clearing there was still the risk that a nest may have been missed or a bird had set up a nest site on the cleared ROW prior to the initiation of any grading or other construction activity. Consequently a migratory bird nest discovery protocol was developed and would be implemented if during construction an active nest site was discovered. This required the continuation of monitoring surveys ahead of grading or other activities in areas where new nests may have established.

The discovery protocol consisted of the following steps:

1. Stop activity and implement temporary buffer;
2. Contact Environmental Inspector;
3. Assess nest and recommend mitigation;
4. Implement mitigation and issue "environmental memorandum" to construction staff and M&NP responsible staff;
5. Communicate with regulators (CWS);
6. Monitor nest;
7. Issue "all clear" once birds have fledged;
8. Proceed with clearing or construction activity; and
9. Document and close.

RESULTS

Consultation
In early March 2000, a preliminary contingency plan was developed. This plan was used as the basis for initial discussions with federal and provincial regulatory agencies. Consultation with CWS and the provincial agencies continued through March and April 2000. As a result of the consultation, NBDELG indicated it had no mandated concerns with the proposed strategy, while NBDNRE indicated the proposed mitigation was acceptable and addressed all of their concerns with respect to migratory birds.

CWS indicated that the strategies and mitigation proposed to protect migratory birds was consistent with options discussed during consultation. CWS was of the opinion; however, that the strategies proposed would be ineffective in preventing the loss of all migratory bird nests in the ROW, particularly those which nest high up in trees as well as very secretive ground nesters. CWS indicated that at the population level, for all but rare species, the loss of one season's production is less significant than the loss/alteration of their habitat due to ROW clearing and long-term maintenance. The estimated 250 hectare altered by clearing of the Saint John Lateral would not be significant at the population level but there is a concern with cumulative effects of many such projects on migratory bird habitat.

In subsequent correspondence to the NEB, CWS acknowledged the consultation efforts of M&NP, but suggested that the strategies proposed were not expected to be effective in preventing the loss of migratory bird nests in the ROW. It was CWS' position that Section 6 of the Migratory Bird Regulations prohibits the taking of migratory birds or their nests, and since considerable nests were expected to be at risk, CWS recommended that clearing be undertaken outside the mid-April to mid- August time frame.

The future of the clearing program was left to the NEB to determine based on the strategies proposed and the results of the consultation, to determine whether clearing of the Saint John Lateral should proceed or be delayed until after mid-August. On May 12, 2000, the NEB sent a letter to M&NP stating, The Board is of the view that M&NP has satisfied the requirements of Condition 13 of Certificate GC-102 and approves the results of M&NP's consultation with CWS, NBDOE, and NBDNR. The NEB further cautioned M&NP that the proposed mitigation measures did not preclude prosecution under the Migratory Bird Convention Act. Clearing of the ROW commenced on June 1.

Migratory bird protection program

Breeding bird surveys and nest monitoring was conducted between May 20 and June 26, 2000. In May, 222 person days were logged over 12 days for an average of 18.5 persons per day to cover nine routes. In June, 387 person days were logged over 26 days, an average of 14.9 person days. This reduction reflected the reduction in crews required over this period as clearing activity progressed. On June 27, the program was reduced to a single crew. Only a small section of the ROW remained to be cleared and this crew was used to monitor active nests and to check for nests in advance of clearing crews.

Monitoring was conducted on May 19–21, May 30–June 2, June 12–15, and June 26–27. The entire rural portion of the Saint John Lateral (95 km) was surveyed twice during the first two surveys, as clearing did not commence until June 1, 2000. Clearing of the ROW subsequently reduced the survey areas to 75 km and 40 km by the time of the fourth survey. A total of 37 active or probable nest sites were found within or immediately adjacent to the ROW (Table 1). Of the 37 nests, 30 fledged, four nests were never confirmed as active, two failed and one had a false start. Species observed included Ruffed Grouse (not a migratory bird), Mallard, Hairy Woodpecker, Downy Woodpecker, Swamp Sparrow, Northern Flicker, Yellow-bellied Sapsucker, Ovenbird, American Redstart, and White-throated Sparrow.

Table 1. M&NP Saint John Lateral bird nests

Kp	Species	Nest type	Status	Fledged
4+000	White-throated Sparrow	Ground	Failed	N/A
4+150	White-throated Sparrow			
4+450	Yellow-bellied Sapsucker	Cavity	Fledged	July 11
6+900	Ruffed Grouse	Ground	Fledged	June 4
10+350	White-throated Sparrow	Ground	Fledged	June 21
11+650	Tree Swallow	Cavity	False start	N/A
12+850	White-throated Sparrow	Ground	Fledged	June 28
13+275	White-throated Sparrow	Ground	Failed	N/A
15+767	Ruffed Grouse	Ground	Fledged	May 30
16+350	Ruffed Grouse	Ground	Fledged	N/A
Shoofly #3 (approx kp 18)	American Robin	Tree	Fledged	July 5
20+800	Hairy Woodpecker	Cavity	Fledged	June 18
21+400	Hairy Woodpecker	Cavity	Fledged	June 27
27+100	Swamp Sparrow	Shrub	Fledged	July 11
28+450	Hairy Woodpecker	Cavity	Fledged	July 12
28+550	Sparrow	Ground	Failed	N/A
39+085	Yellow-bellied Sapsucker	Cavity	Fledged	July 27
39+250	Yellow-bellied Sapsucker	Cavity	Fledged	July 4
Lake Utopia Extension 1+150	Northern Flicker	Cavity	Fledged	??
Lake Utopia Extension 1+800	Hermit Thrush	Ground	Fledged	July 13
Lake Utopia Extension 4+500	American Robin	Ground	Fledged	July 1
40+284	Ovenbird	Ground	Fledged	June 29
40+550	American Redstart	Tree	Fledged	July 4
42+070	Yellow-bellied Sapsucker	Cavity	Fledged	July 10
46+090	Northern Flicker	Cavity	Fledged	??
53+746	Downy Woodpecker	Cavity	Fledged	July 4
54+583	Ruffed Grouse	Ground	Fledged	July 4
60+157	Northern Flicker	Cavity	Unkown	??
67+250	Northern Flicker	Cavity	Fledged	August 8
69+450	Mallard	Ground	Fledged	June 28
71+600	American Robin	Ground	Fledged	July 5
76+550	Hermit Thrush	Ground	Fledged	July 31
83+442	Hermit Thrush	Ground	Fledged	June 24
86+010	American Robin	Tree	Fledged	June 27
87+078	American Robin	Tree	Fledged	??

CONCLUSIONS

Although somewhat controversial, the contingency plan put in place by M&NP appeared to be successful in that nests were identified and mitigation measures were implemented with successful fledging in all but 4 cases. It is difficult to assess the success of the bird nesting deterrent program, as there is no basis to compare the ROW to a similar control. The bird deterrent crew successfully identified nests and the bird survey program was effective in locating nests or nesting activity.

Managing the impacts of pipeline construction on migratory birds as well as the impacts of migratory birds on pipeline construction continues to be a significant issue for pipeline planning and development. The industry has taken a proactive approach to this issue and has produced a guidance document for pipeline companies and continues to participate in research to help better understand the impact of pipeline construction and operation on migratory birds.

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Impact of Natural Gas Pipeline Operation and Maintenance on Long-Term Population Viability of the Threatened Gopher Tortoise

Edward E. Wester and Joe W. Kolb

A natural gas pipeline expansion within the range of the federally threatened "western population" of the gopher tortoise (*Gopherus polyphemus*) resulted in a US Fish and Wildlife Service and Federal Energy Regulatory Commission requirement that the long-term impact of operation and maintenance on the tortoise population within the right-of-way be assessed. In many areas, utility rights-of-way may provide the only suitable habitat for the gopher tortoise. Tortoises excavate burrows in sandy and clayey soils. The study focused on the potential impacts of right-of-way mowing. Machinery used may cause burrows to collapse and lead to tortoise entombment. During the inactive season, 33 occupied burrows in sandy and clayey soils were collapsed in a "worse case" manner with a suitably sized tractor. All but one of the tortoises excavated themselves. Radio telemetry monitoring and observations following tortoise emergence suggest no subsequent mortality, injury, or ill effects. Assuming no burrow protection measures, the observed mortality rate was used to estimate a per mowing event mortality rate of 0.14%. Biannual mowing could result in one mortality every nine years. If current burrow protection measures continue, the current population was estimated to double in 200 years. If burrow protection measures are not implemented, biannual mowing would reduce the estimated, 200-year population size by 12.4%.

Keywords: Pipeline, gopher tortoise, *Gopherus polyphemus*, impact, right-of-way, telemetry, burrow, right-of-way

INTRODUCTION

In 1994–1995, Florida Gas Transmission Company (FGT) constructed 815 miles of natural gas pipeline from Louisiana to south Florida. Approximately 140 miles of the FGT Phase III Expansion Project occurred within the range of the federally threatened "western population" of the gopher tortoise (*Gopherus polyphemus*). Pipeline construction along this portion of the project route, as along most of the Phase III route, occurred within/adjacent to an existing FGT right-of-way (ROW).

On 27 December 1993, the U.S. Fish and Wildlife Service (USFWS) issued a Biological Opinion that authorized both direct and indirect incidental take during temporary displacement of gopher tortoises from the construction corridor and during pipeline construction. The Opinion also authorized incidental take following construction during routine pipeline operation and ROW maintenance. During the Phase III Expansion Project, FGT biologists displaced a total of 87 gopher tortoises from 219 burrows occurring within the construction corridor. A final incidental take report summarizing all project gopher tortoise conservation efforts, as well as the results of a radio-telemetry study of displaced tortoise movements, was submitted to the USFWS in April 1995. Wester and Kolb (1997) summarized FGT's gopher tortoise conservation efforts throughout the Phase III Expansion Project (2,524 gopher tortoises were displaced from 5,934 burrows along the entire project route).

The USFWS incidental take authorization required that FGT develop and implement a study to assess the potential long-term impacts of natural gas pipeline operation and ROW maintenance activities on the threat-

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ened gopher tortoise. Accordingly, the Federal Energy Regulatory Commission (FERC) also incorporated this requirement into its environmental conditions for the Phase III Expansion Project. This paper summarizes the results of a study designed to fulfill these requirements.

Potential impacts to the gopher tortoise associated with natural gas pipeline operation and right-of-way maintenance

Gopher tortoises prefer open, sunny habitats with a well-developed, herbaceous, ground flora (Hallinan, 1923; Landers, 1980; Landers et al., 1980; Auffenberg and Franz, 1982; Diemer, 1986). As such, they are attracted to ruderal habitats (Auffenberg and Franz 1982) and can often be found in relatively high densities on pipeline ROWs. This is especially true in areas where adjacent habitats have been degraded by adverse land-use practices. In many areas, pipeline ROWs provide the only suitable habitat for gopher tortoises. Without such maintained habitats gopher tortoises, and other associated species, might no longer exist. Pipeline operation and ROW maintenance itself; however, may potentially result in adverse indirect and/or direct impacts to the gopher tortoise and its long-term population viability.

Potential adverse indirect impacts

Potential adverse indirect impacts are primarily associated with the tendency of gopher tortoises to congregate on maintained ROWs and may include the following:

1. Increased competition for food as gopher tortoises become increasingly aggregated in limited areas of suitable habitat along a ROW;
2. Increased potential for disease transmission (e.g. upper respiratory tract disease syndrome [URTDS]) as gopher tortoises become increasingly concentrated;
3. Increased potential for adverse social interactions among concentrated gopher tortoises;
4. Decreased reproductive success as egg predators have a greater impact in areas of relatively high gopher tortoise concentrations;
5. Decreased potential for gene flow among local populations of gopher tortoises as dispersing individuals remain on ROW;
6. Increased potential for human take of gopher tortoises from easily identified and accessed gopher tortoise populations; and
7. Increased potential for inadvertent impacts associated with landowner or adjacent land use activities (e.g., plowing/planting of wildlife food plots on ROW, use of ROW for piling and removing timber from adjacent tracts, off-road vehicle activity, etc.).

Given the protracted life history of the gopher tortoise, the reduced abundance of gopher tortoises within the range of the threatened "western population," and the limitations associated with working with gopher tortoises occurring on a pipeline ROW (e.g., landowner consent, landowner impacts, access to adjacent habitats, etc.), meaningful studies of potential adverse indirect impacts associated with pipeline operation and ROW maintenance would be difficult, if not impossible, to conduct.

Potential adverse direct impacts

Potential adverse direct impacts to gopher tortoises primarily are associated with routine and non-routine operation and maintenance activities that must occur along a natural gas pipeline ROW. Routine activities may include maintenance of above ground facilities (valves, metering stations, etc.), rehabilitation of erosion control structures, corrosion testing/repair, leak detection, and periodic mowing of the ROW. Non-routine activities are generally are restricted to emergency repairs of damaged pipelines or facilities. Adverse direct impacts to the gopher tortoise that might result from such activities may include the following:

1. Disruption of essential behaviors such as feeding, courtship, and mating during operation and maintenance activities;
2. Injury or mortality of gopher tortoises hit by vehicles or other equipment operating on the ROW;
3. Injury or mortality of gopher tortoises resulting from a pipeline rupture and subsequent emergency repair efforts; and
4. Potential entombment and mortality of gopher tortoises in burrows inadvertently collapsed by heavy equipment during routine ROW mowing activities.

With the exception of periodic mowing of the ROW, most of the routine activities required to safely and efficiently operate a natural gas pipeline are infrequent and occur at discreet locations. When such activities are necessary, FGT is required to conduct gopher tortoise surveys and, wherever possible, to restrict vehicular traffic to existing trails (as would be the case when visiting most valves, metering stations, etc.). Non-routine activities associated with emergency repairs are rare, and, given the distribution of tortoises along the FGT ROW, have a high probability of occurring in areas unoccupied by gopher tortoises. As such, most pipeline operation and ROW maintenance activities likely pose only a minimal threat to individual gopher tortoises or to long-term gopher tortoise population viability.

Periodic mowing is necessary to control encroachment of woody vegetation on the ROW. More importantly, to benefit the gopher tortoise, FGT is required to conduct mowing operations at a frequency sufficient to maintain its ROW in an herbaceous state (most portions of the FGT ROW are mowed every 2–3 years). ROW mowing; however, routinely requires the use of heavy equipment over the entire length of the ROW and is, therefore, the single activity associated with operation and maintenance of a natural gas pipeline with the greatest potential for adverse direct impacts to the gopher tortoise.

Prior to the Phase III Expansion Project, FGT did not implement specific gopher tortoise protection measures. The ROW was mowed at varying times of the year and no efforts were made to insure that tortoise burrows were not affected. It is possible that some tortoises were killed during mowing operations and it is possible that burrows were inadvertently collapsed and tortoises entombed (although evidence of collapsed burrows was minimal during surveys conducted prior to Phase III). The loss of tortoises that might have occurred during this period had the potential to impact the long-term viability of the gopher tortoise population occupying the FGT ROW.

Following the Phase III Expansion Project, FGT is now required to restrict its mowing operations to the gopher tortoise's inactive season (1 November to 31 March) to minimize the potential for adverse direct impacts to the gopher tortoise. To prevent collapsing of burrows and possible entombment of resident tortoises, FGT is also required to:

1. Conduct pre-mowing gopher tortoise burrow surveys;
2. Mow only using rubber-tired, tractor-drawn bush-hogs;
3. Flag a 15-foot radius around each burrow and restrict mowing equipment from operating within this area; and
4. Clear vegetation within 15 feet of all burrows using only hand-held equipment.

Given these restrictions and requirements, routine mowing, as currently conducted, should pose only a minimal threat to individual tortoises and to long-term gopher tortoise population viability along the FGT ROW.

Restricting mowing to the inactive season requires no additional cost and clearly limits the potential for direct impacts to gopher tortoises that might otherwise be encountered out of their burrows during the active season. Conducting pre-mowing surveys, flagging burrows for avoidance by mowing equipment (then removing after mowing), and hand clearing of vegetation within a 15-foot radius of burrows; however, all require a large expenditure of manpower, time, and cost over the 140 miles of the FGT ROW within the threatened range of the gopher tortoise. Unfortunately, there are no data that indicate to what extent these efforts might actually contribute to enhanced gopher tortoise survival and long-term population viability. If, in the absence of burrow protection measures, gopher tortoises frequently are lost due to entombment in collapsed burrows, the adverse impact on long-term population viability may be severe. If losses of tortoises; however, are minimal over time, the costs of implementing all of these extensive burrow protection measures may not be entirely warranted.

The FGT ROW occupies a very small area (approximately 1,530 acres) within the range of the threatened "western population" of the gopher tortoise. Accordingly, and although it may attract gopher tortoises from a somewhat larger area, the FGT ROW likely supports only a very small fraction of the threatened population and any impacts that occur there will likely have only a minimal impact on the long-term viability of the overall threatened population. There are thousands of miles of other pipeline, power transmission, communications, and highway ROWs; however, within the threatened range. Given their herbaceous groundcover and open canopy, many of these ROWs are likely to be occupied by gopher tortoises. It is also likely that many of these ROWs are routinely mowed or cleared without regard to protection of gopher tortoises or their burrows. And, while some companies are moving toward the use of herbicides to maintain their ROWs (with unknown potential impacts to the gopher tortoise), heavy equipment, which may also collapse burrows, typically is still used for application. If loss of gopher tortoises, particularly due to entombment in collapsed burrows, is occurring with high frequency on these numerous ROWs, the adverse impact on long-term viability of the entire threatened population could be substantial.

Limited data suggest that gopher tortoises may be able to excavate themselves from collapsed burrows (Landers and Buckner, 1981; Diemer and Moler, 1982). These findings; however, were incidental to other studies and the numbers of tortoises involved were very small. No efforts have been made to assess potential variation in the ability of gopher tortoises in different age classes to dig out of collapsed burrows or to determine if varying degrees of soil compactness may affect a tortoise's ability to dig out of a collapsed burrow. Perhaps young tortoises have more difficulty excavating themselves from collapsed burrows than do older individuals. Perhaps burrows in loose, sandy soils are more prone to collapsing than burrows in tight, clayey soils. On the other hand, collapsed burrows in tight, clayey soils may be more difficult to dig out of than those in loose, sandy soils. Unfortunately, the answers to these questions are not known and there have been no efforts to evaluate the potential impacts on long-term gopher tortoise population viability of loss of tortoises due to entombment in collapsed burrows.

FGT study

Routine mowing is the single activity associated with natural gas pipeline operation and maintenance with the greatest potential to cause significant, adverse, direct impacts to individual gopher tortoises and ultimately to long-term gopher tortoise population viability. Knowledge about this critical issue; however, is extremely limited. In light of this, FGT developed and conducted a study to assess the potential impacts of burrow collapsing that might occur during routine ROW mowing operations on the gopher tortoise and its long-term population viability. The study was conducted during the gopher tortoise's inactive season given FGT's seasonal mowing restrictions. The study was developed in cooperation with the USFWS, FERC, and US Forest Service and progress reports were submitted to these agencies throughout the study period.

METHODS

To avoid potential impacts to gopher tortoises within the range of the federally threatened "western population," FGT initially proposed to conduct this research only along its ROW within Florida where gopher tortoises occur on sites with relatively loose, sandy soils. After preliminary interactions with the USFWS; however, FGT modified its proposed study plan to include gopher tortoises on its ROW in Louisiana occurring on sites with tighter, higher clay/silt content soils. FGT's modified study plan was reviewed by the Gopher Tortoise Council and other concerned individuals. The results of these reviews indicated that conducting any portion of the proposed study within the threatened range was controversial. Because of this controversy, FGT and the USFWS subsequently agreed that the study would still be divided into two phases addressing two general classes of soil compactness. Instead of working within the threatened range; however, efforts would be made to establish a captive population of non-threatened gopher tortoises on a site with tight, clayey soils located outside of the threatened range.

Phase I – loose, sandy soils

Phase I of the study was conducted along 11.3 miles of the FGT ROW (milepost 417.1–428.4) within the Wakulla Ranger District of Apalachicola National Forest, Leon Co., Florida (Fig. 1). Apalachicola National Forest was chosen for this portion of the study because soils along the FGT ROW generally are loose sands and are typical of areas generally thought to have historically supported good gopher tortoise populations. This area was also chosen because of the diversity of age classes of tortoises observed along this portion of the FGT ROW during the Phase III Expansion Project. And importantly, working on the Apalachicola National Forest also facilitated unhindered access to adjacent habitats as study tortoises moved off of the FGT ROW. This portion of the study was conducted under a Temporary Special Use Permit issued by the US Forest Service (USFS) and a Scientific Collecting Permit issued by the Florida Game and Fresh Water Fish Commission.

On September 23 and 26, 1996, traps were set at 18 adult burrows and 11 subadult burrows known, or

Fig. 1. Typical aspect – FGT right-of-way, Apalachicola National Forest.

Fig. 2. Phase I tortoise #46 returning to burrow following radio transmitter attachment.

believed, to be occupied by gopher tortoises. Tomahawk wire live traps were used at adult and larger subadult burrows and pit-fall traps were used at smaller subadult burrows. Traps were checked twice daily, in the late morning and late afternoon through October 11 1996.

A total of 23 gopher tortoises (8 adult males, 7 adult females, 8 subadults) were captured and fitted with radio transmitters (AVM Instrument Co.). Captured tortoises were measured, sexed (if mature), age estimated, weighed, and photographed. Radio transmitters were attached to the right-rear carapace using a fast setting epoxy. To avoid potentially affecting carapace growth, transmitters for subadult tortoises were sized such that they could be attached to only one scute. Following transmitter attachment, tortoises were released into the burrows from which they were captured (Fig. 2).

Collapsing burrows

On January 25, 1997, the burrow of one sub-adult gopher tortoise (#45) was found to have been collapsed by heavy vehicle activity on the FGT ROW. During the period of this study, FGT conducted no ROW operation or maintenance actions requiring the use of heavy

Fig. 3. Front tractor tire collapsing Phase I burrow #4046 (tortoise #46) in loose, sandy soils.

Fig. 4. Phase I burrow #4060 (tortoise #25) immediately prior to collapse.

Fig. 5. Burrow #4060 following collapse (note soil compaction and extent of impact to burrow).

equipment within the study area. It is likely that vehicles used by Army ROTC units, occasionally observed training in the vicinity of this burrow, were responsible for its collapse.

On February 3 1997, locations of the 18 remaining telemetered tortoises were determined. By this time, some tortoises had moved to different burrows on the ROW and some had moved to burrows in adjacent habitats. A 30 cm metal spike was driven to ground level at the burrow entrance to permanently mark the original entrance location. The orientation and inclination of the initial burrow path from this point were recorded (to facilitate subsequent efforts that might be necessary to manually excavate burrows). All burrows were also examined with a remote video system to insure occupancy by a gopher tortoise, to confirm transmitter attachment (if possible), and to insure that no protected burrow commensals (e.g., threatened eastern indigo snake) were present.

On February 4 1997, the locations of all telemetered gopher tortoises were reconfirmed using radio telemetry. All 18 burrows were again inspected with a remote video system to verify tortoise occupancy and absence of vertebrate burrow commensals. Following this final inspection, burrows were collapsed using procedures believed to produce the greatest possible degree of collapse. All burrows were collapsed by driving over them with a Ford 345C tractor (with front-end loader for increased weight). The tractor was driven such that the front and rear wheels on one side rolled along the burrow path, presumably resulting in a much greater length of burrow collapse than would be caused by rolling across its path (Fig. 3). In several instances, the location of burrows along the edge of the ROW or in adjacent habitat required slower maneuvering of the tractor and even backing the tractor out over a burrow a second time, again likely resulting in a greater degree of collapse than might be expected during routine mowing operations.

Immediately prior to collapsing a burrow, a 1 mm diameter cable with a 2 cm diameter ring on each end was inserted approximately 2 m into each burrow. Following collapse, the cable was slowly withdrawn until resistance was felt. The remainder of the cable was then pulled through the affected soil and measured to determine the approximate length of the burrow that had been collapsed.

All burrow collapsing activities were videotaped. Pre-collapse and post-collapse photographs were also taken of all burrows (e.g., Figs. 4 and 5).

Monitoring of collapsed burrows/entombed gopher tortoises
Following collapsing of burrows, the study site was visited once weekly through June 21, 1997. All burrows were visually examined for signs of tortoise excavation. Radio telemetry was also used to determine if tortoises remained in collapsed burrows. When a gopher tortoise was found to have excavated itself from a collapsed burrow, the burrow was photographed and the distance of the new burrow entrance from the spike that had been previously placed at the original entrance was measured. It was also determined if the new burrow opening was located on or off the original burrow path. Once tortoises excavated themselves

from collapsed burrows, their movements continued to be monitored weekly through June 21th (or until transmitter failure).

Monitoring of FGT study by agency biologists
Throughout the study period, FGT biologists were frequently accompanied by biologists from the US Forest Service. Mr. Art Rohrbacher (National Forests in Florida - Supervisor's Office) accompanied FGT biologists throughout all phases of the study and was present during burrow collapsing. Mr. Greg Titus (Supervisor's Office) and Ms. Susan Fitzgerald and Mr. Jim Rhule (Apalachicola Ranger District) also occasionally accompanied FGT biologists during various phases of the study. On May 6, 1997, Ms. Joan Berish and Mr. Rick McCann (Florida Fish and Wildlife Conservation Commission) accompanied FGT biologists during post-collapse burrow monitoring/tortoise tracking efforts.

Phase II – tight, clayey soils
Phase II of the study was conducted near Auburn, Alabama. This phase of the study was conducted using a captive population of gopher tortoises to avoid potential impacts to tortoises on sites with tight, clayey soils within the threatened range.

Study site selection
Five potential sites for establishment of a captive study population were chosen in Chambers, Lee, and Macon Cos., Alabama in April/May 1995. Soil samples were taken from all sites for comparison to samples taken from four locations along the FGT ROW in Louisiana and Mississippi in March 1995. Samples of clayey soils along the FGT ROW were taken from sites occupied by gopher tortoises. Soil samples were analyzed by Dr. Charles Mitchell (Department of Agronomy and Soils, Auburn University). Based on these analyses, a site in Lee Co. was deemed to have soils very similar in clay/silt content and compatibility to sites with tight, clayey soils along the FGT ROW in Louisiana and Mississippi.

Captive gopher tortoise population A
Through interactions with Ms. Joan Berish (Florida Game and Fresh Water Fish Commission [GFC]), 11 adult gopher tortoises that had been taken from poachers in Florida were made available to FGT for use in this study. Copies of permits from the GFC authorizing removal of these tortoises from Florida for use in this study and from the Alabama Department of Conservation and Natural Resources authorizing importation into Alabama for this study were obtained. Two additional tortoises that had previously been held in captivity for educational purposes in Alabama were also made available for the study. All captive tortoises were measured, sexed, age estimated, weighed, and photographed.

Fig. 6. Phase II-A tortoises basking at entrances to starter burrows.

Captive gopher tortoises were released into individual enclosures constructed during May 12–15, 1995. Enclosures averaged approximately 24 m^2 and were provided with shade and ample herbaceous vegetation for feeding (Fig. 6). Following their release into the enclosures, tortoises were monitored daily for two weeks. During this initial period, only one gopher tortoise began to excavate its own burrow. All other tortoises used the shaded areas of their enclosures for refuge. Accordingly, starter burrows were dug with post-hole diggers to a length of approximately 0.75 m in the 12 enclosures without burrows. Starter burrows were dug at an angle similar to that measured for actual tortoise burrows on Apalachicola National Forest and previously observed on the FGT ROW in the threatened range. Tortoises immediately began to use the starter burrows (Fig. 6). Enclosures were monitored a minimum of twice weekly thereafter.

By mid June 1995, captive tortoises generally were not lengthening their starter burrows. It was believed that the unusually dry conditions, coupled with the tight, clayey soils of the site, made burrow excavation difficult. A sprinkler system was installed to increase the chances that tortoises would lengthen their burrows and to insure continued vegetation growth for food. On September 18, 1995; however, mean burrow length was only 1.0 m (range 0.7–2 m). In late May 1996, mean burrow length had increased slightly to 1.4 m (range 0.8–2.7 m).

Given the slow rate at which captive tortoises were excavating their burrows, efforts were made to encourage tortoises in shorter burrows to lengthen their burrows by drilling a small, 10 cm diameter "pilot hole" extending past the end of the burrow. Pilot holes were drilled in seven of the shortest burrows using a handheld, power auger with a 3 m bit/extension held at the same angle as the initial burrow path. By late August 1996, mean burrow length (depth tortoise could actually reach – not pilot hole) had increased to 1.6 m (range 1.1–2.7 m). In late September/early October, evidence of fresh excavation from burrows was frequently observed. On October 28th, mean burrow length had increased to 2.1 m (range 1.5–3.4 m).

On February 7, 1997, seven burrows were found to be 2.3–3.4 m in length. The remaining six burrows were less than 1.8 m long. On February 8th, these seven burrows were collapsed using procedures and protocols similar to those in Phase I of this study. A John Deere 310 backhoe was used to collapse these seven burrows. Burrows were collapsed following a period of rain when soils were relatively moist and more easily disturbed. As during Phase I collapsing efforts, the heavy equipment used, slow maneuvering speed, and path along the burrow should have resulted in a greater degree of burrow collapse than might be expected during typical FGT ROW mowing operations. Following collapsing, all burrows were visually examined at least once daily for signs of tortoise excavation.

Captive gopher tortoise population B

Given the relatively small number of tortoises in captive population A with burrows sufficiently long to collapse in winter 1997, it was decided that efforts would be made to repeat Phase II of the study during winter 1998.

In June 1997, FGT was made aware of a group of long-term captive gopher tortoises for which placement was being sought. These tortoises were originally taken from a private site near Ozark, Alabama 20–25 years ago and kept by an individual. Several additional tortoises in this group hatched in captivity over time. To increase sample size for Phase II of the study and to include subadult tortoises, FGT agreed to take nine of these tortoises (7 adults and 2 subadults). On July 15th, these nine additional tortoises, constituting captive population B, were placed into individual enclosures constructed adjacent to those housing captive population A. Given the previous experience with the apparent reluctance of captive tortoises to quickly excavate new burrows, an appropriately sized starter burrow was dug in each enclosure and a power auger was used, as described previously, to drill a 10 cm diameter pilot path for the burrow. All tortoises immediately began to lengthen their burrows. On September 30th, mean burrow length for tortoises in captive population #2 was 2.6 m (range 1.8–3.2 m). On February 14, 1998, seven burrows were found to be 2.4–3.5 m in length. The remaining burrow was only 1.8 m in length. These seven burrows were collapsed using the same backhoe and procedures as previously described for captive population A.

Analyses

Population viability analysis and other analyses

To assess the potential long-term impacts associated with entombment and mortality of gopher tortoises in burrows inadvertently collapsed during routine mowing operations, the results of this study were incorporated into population viability models. Population viability analyses were performed using the program Vortex (ver 8.21) (Miller and Lacy, 1999). The Vortex program is "a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wildlife populations" (Lacy et al., 1995). While not the primary focus of this study, variation in burrow collapse length, days required to excavate from collapsed burrows, and distance of new burrow entrance from original pre-collapse location were also examined between soil types and sexes. The methodology and detailed results of these analyses are not presented in this paper but will be presented in another forum.

RESULTS

Phase I – loose, sandy soils

All 19 gopher tortoises in loose, sandy soils successfully excavated themselves from their collapsed burrows. Detailed results for Phase I of the study are summarized in Table 1.

Once tortoises excavated themselves from their collapsed burrows, monitoring of their movements continued through June 1997. Some tortoises continued to use their original burrows while others moved to nearby existing/new burrows. Study tortoises were frequently observed at their burrow entrances or short distances down in their burrows. There was no evidence of any mortality, injury, or other ill effects following emergence of tortoises from their collapsed burrows.

Phase II – tight, clayey soils

Captive population A

All seven gopher tortoises in captive population A in tight, clayey soils successfully excavated themselves from their collapsed burrows. Most tortoises excavated themselves within three weeks, typically during/following periods of heavy rainfall when depressions over their collapsed burrow entrances were often flooded (Fig. 7). Two tortoises; however, remained in their collapsed burrows throughout extended periods of rainfall and emerged during dryer conditions as long as 15 weeks following burrow collapse. Given that collapsed burrows in Phase II-A were monitored daily, it was occasionally possible to observe tortoises at the time of, or shortly following, emergence from their collapsed burrows. Detailed results for Phase II-A are summarized in Table 2.

Captive population B

Seven of the eight gopher tortoises in captive population B in tight, clayey soils successfully excavated themselves from their collapsed burrows. One adult, male tortoise did not excavate itself and was subsequently found to have died in its burrow. Two tortoises

Table 1. Summary of results for Phase I – loose, sandy soils

Tortoise No.[1]	Burrow No.	FGT milepost	Carapace length (cm)	Sex	Collapse length (cm)	Days to excavate (maximum[2])	Distance back[3] (cm)	On/off original path[4]
41	4065	417.25	24.8	male	94	81	30	on
52	4052	417.50	11.0	subadult	51	39	36	off
2	4002	418.85	23.4	male	86	55	46	off
18	4059	419.20	24.4	male	99	46	89	on
326	4064	420.05	27.3	female	69	103	76	off
9	4009	420.30	29.3	female	71	55	48	on
173	4063	420.50	27.0	male	38	91	25	on
4	4049	421.15	24.6	male	89	69	38	off
3	4062	421.20	26.5	male	152	?[5]	?[5]	?[5]
214	4004	421.25	26.9	female	107	60	114	on
25	4060	422.50	27.7	female	91	69	190	off
47	4047	423.05	17.0	subadult	64	55	8	on
20	4061	424.50	24.9	male	79	91	56	off
46	4046	426.30	21.2	subadult	41	69	20	on
45	4045	426.55	14.0	subadult	?[6]	34	15	on
32	4032	427.20	14.3	subadult	53	60	30	off
31	4031	427.50	16.9	subadult	53	34	15	on
30	4066	427.60	15.2	subadult	107	55	?[7]	?[7]
38	4038	427.70	21.0	subadult	137	46	10	on

[1]Tortoise Nos. 326, 173, and 214 were previously captured and temporarily displaced from the ROW during Phase III construction in 1994. Their original numbers were retained.

[2]Collapsed burrows were visited only once weekly. For purposes of this study it is assumed that tortoises excavated themselves on the day the burrow was found reopened.

[3]Distance of new burrow entrance back from original, pre-collapse entrance location.

[4]Location of new burrow entrance relative to original burrow path.

[5]Excavation date and location not known.

[6]Collapse distance unknown. Burrow was collapsed by unauthorized vehicle activity on ROW prior to the date of collapsing remaining burrows by FGT.

[7]Tortoise found excavated and in new burrow, but emergence location could not be found.

Table 2. Summary of results for Phase II-A – tight, clayey soils

Tortoise No.	Carapace length (cm)	Sex	Collapse length (cm)	Days to excavate	Distance back (cm)	On/off original path
1	28.8	female	81	20	61	on
2	24.3	male	46	80	38	on
4	24.2	male	94	21	56	on
6	24.0	male	61	107	48	on
7	24.7	female	97	19	66	on
10	28.4	female	147	12	89	on
12	30.0	female	109	14	76	on

Fig. 7. Flooded depression over collapsed Phase II-A burrow entrance two days prior to emergence of tortoise #4.

excavated themselves two days following burrow collapse during a period of heavy rainfall. Five of the remaining tortoises excavated themselves from collapsed burrows within 34–66 days. As during Phase II-A, it was occasionally possible to observe tortoises at the time of, or shortly following, emergence from their collapsed burrows (Fig. 8). Detailed results for Phase II-B are summarized in Table 3.

Following emergence of all other tortoises in captive population B, daily monitoring of the collapsed burrow of tortoise #13 continued. On 17 August 1998 (184 days post-collapse), a 5–7 cm hole was found to have eroded through the roof of the burrow following two days of heavy rainfall. The hole was located approximately 35 cm back along the path of the burrow from the original entrance location. The roof of

Table 3. Summary of results for Phase II-B – tight, clayey soils

Tortoise No.	Carapace length (cm)	Sex	Collapse length (cm)	Days to excavate	Distance back (cm)	On/off original path
6	25.6	female	66	43	33	on
8	21.1	subadult	15	2	0	on
9	26.4	female	46	37	33	on
10	24.7	male	61	34	53	on
13	25.3	male	38	died	–	–
14	18.8	subadult	18	66	0	on
19	22.7	female	28	42	23	on
21	27.5	male	30	2	46	on

Fig. 8. Phase II-B tortoise #9 basking as it emerges following successful excavation from its collapsed burrow.

the burrow at this point was approximately 5 cm thick. The carapace of tortoise #13 was observed immediately under the eroded hole and there was no response to stimulation. The burrow was excavated and the tortoise was found to be dead. There was no flesh remaining and odor was minimal, suggesting that this individual had been dead for an extended period. The shell was located approximately at the point to which the burrow had been collapsed and it did not appear that this tortoise had made any attempt to excavate itself.

Time required for gopher tortoises to excavate themselves from collapsed burrows

The mean amount of time (maximum) required for gopher tortoises in loose, sandy soils to excavate themselves from their collapsed burrows was 63.9 days ($n = 16$; SE $= 4.912$). The mean amount of time required for gopher tortoises in tight, clayey soils to excavate themselves from their collapsed burrows was 35.6 days ($n = 14$; SE $= 8.156$).

Burrow collapse lengths and tortoise excavation locations

The mean collapsed length of gopher tortoise burrows in loose, sandy soils was 76.4 cm ($n = 16$; SE $= 6.648$. Mean collapsed length of burrows in tight, clayey soils was 64.2 cm ($n = 14$; SE $= 10.172$). There was no relationship between burrow collapse length and soil type.

POPULATION VIABILITY

At every stage of this study, efforts were made to create a "worst-case scenario" regarding the degree of burrow collapse and thus the potential for gopher tortoise mortality. All evidence indicates that no mortality occurred in loose, sandy soils. In tight, clayey soils, one adult tortoise did not excavate itself from its collapsed burrow. The cause of this individual's death is not known. However, given the apparent ease with which other tortoises in tight, clayey soils excavated themselves from collapsed burrows (e.g., in some instances simply pushing up the collapsed burrow roof or pushing through the roof during periods of rainfall), it is somewhat surprising that this tortoise did not excavate itself. This is especially true considering that only 38 cm of this tortoise's burrow was collapsed and rainfall alone ultimately opened a hole through the relatively thin (5 cm) burrow roof. It is certainly possible that this tortoise died of natural causes or for other reasons not directly related to its burrow being collapsed (e.g., old age, disease, starvation [although all of these factors could have impaired the tortoise thereby making excavation from the burrow more difficult]). It is also possible that heavy rains resulted in burrow flooding and this individual drowned. Again though, other tortoises seemed to be able to push through rain-softened burrow roofs with relative ease and one tortoise in captive population A remained in its burrow for 107 days through multiple periods of extended, heavy rainfall.

Whether this tortoise died as a direct/indirect result of its burrow being collapsed, or for some other unrelated reason, will never be known. However, for the purposes of this analysis it is assumed that this individual died solely as a result of its entombment in a collapsed burrow. Accordingly, the mortality rate for gopher tortoises in collapsed burrows on sites with tight, clayey soils would be approximately 7% (1 out of 15 tortoises = 6.67%, rounded up to be conservative).

This mortality rate; however, does not directly equate to an estimated per mowing event mortality rate for gopher tortoises on the FGT ROW.

Estimated gopher tortoise mortality for each mowing event

Currently, FGT is required to conduct gopher tortoise burrow surveys immediately prior to mowing its ROW. However, for purposes of this analysis, it is assumed that no gopher tortoise burrow surveys are done prior to mowing of the ROW and no specific burrow protection measures are implemented.

To calculate an estimated mortality rate that might result from collapse of gopher tortoise burrows during a routine mowing event on the FGT ROW, several factors must be considered. These include distribution of burrows among soil types, burrow occupancy rates, potential for actual burrow impact, and potential operator avoidance of burrows. Based on a thorough analysis of these variables, the estimated gopher tortoise mortality rate for each FGT ROW mowing event is 0.14%.

Population viability analyses

Gopher tortoises distributed along the 140 miles of the FGT ROW within the threatened range obviously do not constitute a single biological population. Rather, they exist as a series of loose aggregations, sometimes separated from each other by several miles. However, from an administrative and management perspective, gopher tortoises occurring along the FGT ROW do constitute a "population." For that reason (and for potential applicability to gopher tortoise populations that better satisfy traditional biological concepts of a population), the population viability analyses treat gopher tortoises distributed along the FGT ROW as a single population.

The basic concept behind these analyses is to first develop a model reflective of how a gopher tortoise population, unaffected by tortoise mortality associated with mowing, might reasonably be expected to respond over time given our basic knowledge about tortoise population biology. For the purposes of this study a 200-year time frame is used. Once a theoretically "unaffected" population has been modeled, tortoise mortality resulting from entombment in burrows collapsed during ROW mowing can be introduced and its potential impact on long-term population viability estimated.

Modeling the FGT gopher tortoise population

As with gopher tortoise populations throughout the species' range, much is unknown about specific characteristics of the FGT population. Therefore, many variables are estimated based on available literature and previous gopher tortoise population viability work (i.e., Cox et al., 1987).

Table 4. Estimated reductions in 200-year population size (hypothetical Population D) given varying frequencies of right-of-way mowing

Mowing frequency	Final population size	% Reduction
None	339	–
1 year	261	23.0%
2 years	297	12.4%
3 years	310	8.6%
4 years	318	6.2%
5 years	320	5.6%

Results of population viability analyses

Based upon the performance of five modeled populations, without mortality associated with collapse of burrows during mowing, the FGT gopher tortoise population can be expected to grow from approximately 160 tortoises now to approximately 320–366 tortoises within 200 years.

All of the hypothetical populations performed similarly over time. Mean final population size, based on all of these models combined, would be approximately 344 tortoises. This equates to a long-term annual population growth rate of 0.385% and is considered reasonable for a long-lived, slow to mature species like the gopher tortoise.

Under an annual mowing regime, the estimated gopher tortoise mortality rate associated with collapse of burrows during mowing is 0.14%. When this mortality rate is incorporated into population viability analyses for the five model populations, it is estimated that the FGT gopher tortoise population will grow from approximately 160 tortoises to approximately 251–278 tortoises within 200 years.

Again, all of the hypothetical populations performed similarly over time. Each population exhibited a reduction in final population size of approximately 21–24% when mortality associated with collapse of burrows during annual mowing was incorporated into the model. Mean final population size, based on all of these models combined, would be approximately 264 tortoises. This equates to a reduced long-term annual population growth rate of 0.250%.

A reduction in mowing frequency would obviously reduce the impact that associated mortality would have on long-term gopher tortoise population growth. Of the five modeled populations, Population D best represents an average of all of the models. Using Population D as the model, the reduction in final population size with varying mowing frequencies, relative to unaffected population growth, is summarized in Table 4.

DISCUSSION

At every stage of this study and during subsequent analyses, efforts were made to maximize the potential for impact to individual tortoises and long-term gopher tortoise population viability:

- burrows were compacted in a manner that would result in the greatest degree of collapse;
- equipment used to collapse burrows was heavier than that typically used for mowing;
- equipment was maneuvered directly along the burrow path;
- many burrows were compacted multiple times given the constraints of their locations or just to actually cause them to collapse; and
- in tight, clayey soils, burrows were compacted during periods when soil moisture was high and burrows were most vulnerable to impact.

Despite these intensive efforts; however, there was no tortoise mortality in loose, sandy soils and only one tortoise mortality in tight, clayey soils.

Factors that could ultimately result in the mortality of a gopher tortoise confined to a collapsed burrow may include, hypoxia/hypercarbia, starvation, and burrow flooding. Ultsch and Anderson (1988) measured oxygen and carbon dioxide levels in gopher tortoise burrows in both sandy and clayey soils. They found that O_2 and CO_2 concentrations fluctuate along the lengths of tortoise burrows and that respiratory conditions were worst at ends of burrows during warmer periods of the year. They concluded; however, that the degree of hypoxia and hypercarbia observed in sandy soils was not sufficient to cause physiological stress to gopher tortoises. Tortoise burrows in clayey soils exhibited mild hypoxia and concentrations of CO_2 sometimes rose to levels considered to be of potential physiological consequence.

Although no efforts were made to monitor O_2 and CO_2 levels during this study, it might reasonably be expected that the threat of physiologically meaningful hypoxia/hypercarbia would be heightened in collapsed burrows. Some tortoises; however, in Phase II (tight, clayey soils) of this study did not emerge from their collapsed burrows for considerable periods of time. One tortoise did not excavate itself for 107 days. In captive population #2 (which included the one mortality), excavation times were shorter but some tortoises still remained in their collapsed burrows for as long as 66 days. All of these tortoises that excavated themselves appeared to have suffered no ill effects and exhibited typical behavior patterns following emergence. Given that these individuals were able to excavate themselves after such extended periods, it appears unlikely that hypoxia or hypercarbia would be responsible for the one observed mortality.

Similarly, given the lengthy periods that other tortoises in both sandy and clayey soils remained in their collapsed burrows, it appears unlikely that starvation resulted in the one tortoise mortality. Tortoises as a group are well known for their ability to survive extended periods without feeding. During FGT's Phase III Expansion Project, some gopher tortoises in Louisiana and Florida remained in their burrows for several months during the active season and ultimately had to be excavated with backhoes (Wester and Kolb, 1997).

Gopher tortoise burrows, particularly those in soils with increased clay content, are prone to flooding (Means, 1982). Burrow flooding is most common in the winter months when tortoises can often be heard retreating into water and can sometimes be observed with remote video systems partially or totally submerged (E. Wester pers. observ.). Typically, burrows are not flooded all the way up to the entrance and some length of the burrow remains open. Occasionally burrows can be completely flooded but the resident tortoise still has direct access to the atmosphere. In the case of collapsed burrows, if total burrow flooding occurs, the resident tortoise may be subject to drowning. Several tortoises in Phase II of this study excavated themselves from collapsed burrows during periods of heavy rainfall. Upon excavation their burrows were observed to be flooded. It is not known if they were already flooded or if they flooded following excavations. Collapsing efforts left depressions at most burrow entrances that accumulated water during heavy rains. It is possible that as tortoises emerged, pooled water rushed into burrows. Nevertheless, on each of these occasions, other tortoises remained in their potentially flooded, collapsed burrows with no apparent ill effects. It also appeared that when tortoises did excavate themselves during periods of heavy rainfall (and potentially flooded burrows), they did so with relative ease. Soils were saturated at these times and presumably required minimal effort to dig through, or in some cases to simply push up through to the surface. As such, it appears unlikely that the one tortoise mortality resulted solely from burrow flooding.

The exact cause of the mortality of one gopher tortoise in tight, clayey soils cannot be known. However, the apparent ease with which other tortoises in both soil types excavated themselves from collapsed burrows suggests that other factors (e.g., disease, parasites, old age) may have been involved. Obviously, gopher tortoises die occasionally of natural causes. The death of this individual may have simply been coincidental with this study. It can also be argued; however, that mortality of a diseased/old tortoise might well be hastened by its confinement in a collapsed burrow. In such circumstances, a weakened tortoise may suffer greater physiological impact from hypoxia/hypercarbia or starvation, or may be less able to easily excavate itself from a flooded burrow. Whether such a diseased/old tortoise would ultimately contribute to long-term population viability is unknown and would require substantial additional investigation.

While the one tortoise mortality observed in this study may not truly have been the result of entombment in a collapsed burrow, it is unreasonable to assume that no tortoise mortality will ever occur as a result of inadvertent collapsing of burrows during ROW mowing operations. As such, and given efforts to illustrate a worst-case scenario, the loss of this individual was assumed to be the direct result of burrow collapsing. It was also assumed that this tortoise would have been a functional member of the reproductively active population in the future.

If no burrow protection measures (i.e., pre-mowing surveys, burrow marking, and hand clearing of vegetation around burrows) are implemented, it is estimated that the maximum gopher tortoise mortality rate would be approximately 0.14% for each routine ROW mowing event. Therefore, and given the estimated 160 individuals in the FGT population, a maximum of 0.224 gopher tortoises would be expected to be lost as a result of each mowing event. At FGT's current 2/3-year mowing frequency this equates to estimated maximum of one gopher tortoise mortality every 9–13.5 years. Even if FGT were to mow its ROW annually on all sites with gopher tortoises it is estimated that there would be a maximum loss of only one gopher tortoise every 4.5 years. As the FGT population grows over time, total mortality will obviously increase but even if the population were to double in size the expected loss would still be quite low (e.g., two mortalities every 9–13.5 years given a 2/3-year mowing regime).

Although these mortality rates are low, for a species like the gopher tortoise with its protracted life-history, even minimal losses can have an impact on long-term population viability. If no gopher tortoise mortality occurs as a result of ROW mowing operations (as is theoretically the case now given required burrow protection measures), it is estimated that the FGT population will grow to approximately 320–366 individuals in 200 years. If burrow protection measures are not implemented, the FGT population would still be predicted to grow, but at a slower rate. The extent of the reduction in long-term population growth rate is simply a function of mowing frequency. As mowing frequency decreases, mortality decreases, population growth rate increases, and the estimated 200-year population size increases.

Annual mowing would obviously have the greatest impact, reducing estimated 200-year population size approximately 21–24% to 246–278 tortoises (Table 6). If hypothetical Population D is considered to be a representative example (339 estimated tortoises at 200 years – Table 7), decreasing the mowing frequency to once every two years is estimated to reduce the 200-year population size approximately 12.4% to 297 individuals. Mowing once every three years results in an 8.6% reduction in estimated population size to 310 tortoises, every four years = 6.2% (318 tortoises), and once every five years = 5.6% (320 tortoises). Again, however, even under the most intensive mowing regime, the FGT gopher tortoise population would still be expected to exhibit long-term growth.

Even under the most intensive annual mowing regime, estimated maximum gopher tortoise mortalities are well within the incidental take limits that have already been authorized for maintenance and operation of the FGT ROW. As discussed in the USFWS Biological Opinion for the Phase III Expansion Project, FGT is permitted "direct take up to 5 gopher tortoises per year along the pipeline right-of-way during maintenance operations." To date, there has been no known incidental take of gopher tortoises during ROW mowing operations or other maintenance activities. If no burrow protection measures are implemented and the FGT ROW continues to be mowed every 2–3 years, it is estimated that a maximum of only 1.5 gopher tortoises would be lost approximately every 9–13.5 years (over a 200-year period). Such a loss amounts to only 2.2–3.3% of FGT's currently authorized incidental take limit.

Reducing mowing frequency clearly reduces the number of gopher tortoises that might be lost and significantly reduces the impact on long-term gopher tortoise population viability. A reduced mowing frequency; however, can also result in diminished habitat quality as the density of woody vegetation increases and herbaceous groundcover decreases. A mowing frequency of once every 2–3 years (preferably 3) probably represents a good compromise between minimizing impacts to long-term gopher tortoise population viability and maintaining habitat quality.

The estimated gopher tortoise mortality rate (0.14%) associated with each mowing event (without burrow protection measures) is critical to the population viability analyses and is certainly subject to some degree of error. Again, however, it must be stressed that efforts were made at every stage of this study and at every step in calculating this mortality rate to insure that any error would result in an overestimate of the gopher tortoise mortality that might actually occur. As such, it is not unlikely that actual mortality rates might be lower and the impact on long-term population viability might be reduced. Further studies involving larger sample sizes and monitoring of actual mowing efforts would be required to refine the estimated mortality rate resulting from entombment of gopher tortoises in collapsed burrows.

CONCLUSIONS

Natural gas pipeline operation and ROW maintenance entails a number of activities that could result in adverse impacts to individual gopher tortoises and to long-term viability of the resident population. Most of these activities; however, (e.g., maintenance of above ground facilities, rehabilitation of erosion control structures, corrosion testing, etc.) are infrequent, occur at discrete locations, involve minimal heavy equipment use, and thus pose minimal threat to gopher tortoises. In contrast, routine mowing of a natural gas pipeline ROW requires the extensive use of heavy equipment which could potentially have substantial adverse impacts on individual tortoises and long-term population viability. At present; however, FGT is restricted to mowing during the inactive season and is required to conduct gopher tortoise burrow surveys prior to each mowing event. FGT is then required to flag a 15-foot radius around each burrow and to hand clear vegetation within this area. Therefore, it can be reasonably concluded that current FGT operation and maintenance activities are likely to have minimal or no direct adverse impacts on the long-term viability of the gopher tortoise population occurring on its ROW.

Protecting gopher tortoise burrows in conjunction with minor maintenance and operation activities requires minimal effort and cost. However, given the approximately 400 gopher tortoise burrows distributed along the FGT ROW within the threatened range, conducting burrow surveys, flagging burrows, and hand clearing of vegetation around burrows requires a substantial expenditure of manpower, time, and cost. The results of this study show that if burrow protection measures are not implemented, some gopher tortoise mortality may occur as a result of entombment in burrows collapsed during mowing operations. This mortality will also have some impact on long-term population viability. The numbers of gopher tortoises; however, that might actually be lost are small and far less than the incidental take limits that have already been authorized for maintenance and operation of the FGT pipeline.

Prior to the Phase III Expansion Project, FGT mowed its ROW without specific regard for protection of gopher tortoises. The ROW was mowed at varying times of the year, no pre-mowing burrow surveys were conducted, burrows were not flagged for avoidance by equipment, and hand clearing was not employed around burrows. Yet, as evidenced by the number of tortoises temporarily displaced prior to Phase III construction (and the number of tortoises occupying burrows in those portions of the existing ROW that were not affected by construction), gopher tortoises had persisted on the FGT ROW despite the potential adverse impacts associated with routine mowing. Even today throughout most of the FGT ROW system in Florida there are no specific burrow protection requirements associated with ROW mowing and gopher tortoise abundance continues to remain high. As such, and given the results of this study, it appears that the intensive and costly efforts currently required for protection of gopher tortoise burrows during ROW mowing may not be entirely justified.

REFERENCES

Alford, R. 1980. Population structure of *Gopherus polyphemus* in northern Florida. J. Herpetol., 14: 177–182.

Auffenberg, W. and R. Franz. 1982. The status and distribution of the gopher tortoise (*Gopherus polyphemus*). pp. 95–126. In R.B. Bury (Ed.), North American tortoises: Conservation and Ecology. U.S. Fish Wild. Ser. Wild. Res. Rept. 12.

Auffenberg, W., and J.B. Iverson. 1979. Demography of terrestrial turtles. pp. 541–568. In M. Harless and H. Morlock (Eds.). Turtles: Perspectives and Research. Wiley International, New York.

Arata, A.A. 1958. Notes on the eggs and young of *Gopherus polyphemus* (Daudin). Quart. J. Florida Acad. Sci., 21: 274–280.

Brode, W.E. 1959. Notes on the behavior of *Gopherus polyphemus*. Herpetologica, 15: 101–102.

Cox, J., D. Inkley, and R. Kautz. 1987. Ecology and habitat protection needs of gopher tortoise (*Gopherus polyphemus*) populations found on lands slated for large-scale development in Florida. Florida Game and Fresh Water Fish Comm., Nongame Wild. Prog. Tech. Rept. 4.

Diemer, J.E. 1986. The ecology and management of the gopher tortoise in the southeastern United States. Herpetologica, 42: 125–133.

Diemer, J.E. and P.E. Moler. 1982. Gopher tortoise response to site preparation in northern Florida. Proc. Annu. Conf. Southeast. Fish and Wildl. Agencies., 36: 634–637.

Gourley, E. 1969. Orientation of the gopher tortoise (Daudin). PhD Dissertation, Univ. Florida, Gainesville. 127 pp.

Hallinan, T. 1923. Observations made in Duval County, northern Florida, on the gopher tortoise (*Gopherus polyphemus*). Copeia, 1923: 11–20.

Iverson, J. 1980. Reproduction in fresh water and terrestrial turtles in north Florida. Herpetologica, 33: 205–212.

Landers, J.L. 1980. Recent research on the gopher tortoise and its implications. pp. 8–14. In Franz, R. and R.J. Bryant (Eds.). The dilemma of the gopher tortoise - is there a solution? Proc. 1st Ann. Mtg. Gopher Tortoise Council. Florida State Museum, Gainesville, FL.

Landers, J. and J. Buckner. 1981. The gopher tortoise: effects of forest management and critical aspects of its ecology. Southlands Exp. For. Tech. Note No. 56.

Landers, J., W. McRae, and J. Garner. 1982. Growth and maturity of the gopher tortoise in southwestern Georgia. Bull. Florida St. Mus., 27: 81–110.

Landers, J., J. Garner, and W. McRae. 1980. Reproduction of the gopher tortoise (*Gopherus polyphemus*) in southwestern Georgia. Herpetologica, 36: 353–361.

Means, D.B. 1982. Responses to winter burrow flooding of the gopher tortoise (*Gopherus polyphemus* Daudin). Herpetologica, 38: 521–525.

Miller, P.S. and R.C. Lacy. 1999 VORTEX: A Stochastic Simulation of the Extinction Process. Version 8 User's Manual. Conservation Breeding Specialist Group (SSC/IUCN). Apple Valley, MN. 125 pp.

Palmer, B.D. and L.G. Guillette, Jr. 1988. Histology and functional morphology of the female reproductive tract of the tortoise *Gopherus polyphemus*. Amer. J. Anat., 183: 200–211.

Ultsch, G.R. and J.F. Anderson. 1988. Gas exchange during hypoxia and hypercarbia of terrestrial turtles: a comparison of a fossorial species (*Gopherus polyphemus*) with a sympatric nonfossorial species (*Terrapene carolina*). Physiol. Zool., 61: 142–152.

Wester, E.E. 1995. Distribution and status of the threatened gopher tortoise, *Gopherus polyphemus*, on Camp Shelby, Mississippi. Mississippi Military Dept., Jackson, MS. v + 357 pp.

Wester, E.E. and J.W. Kolb. 1997. Conservation of the gopher tortoise and associated species during construction of the Florida Gas Transmission Company Phase III Expansion Project. pp. 333–340. In J.R. Williams, J.W. Goodrich-Mahoney, J.R. Wisniewski, and J. Wisniewski (Eds.), Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. Elsiver Sci. New York. x + 511 pp.

Wester, E.E. and T.D. Haas. 1995. Distribution threatened gopher tortoise (*Gopherus polyphemus*) on Priority Soils, DeSoto National Forest. US Forest Service, Jackson, MS. 414 pp.

Wester, E.E. and C.K. Swing. 1992. Biological Assessment of the effects of continued/proposed military training activities on the federally threatened gopher tortoise, *Gopherus polyphemus*, on selected lands at Camp Shelby, Mississippi. Mississippi Military Dept., Jackson, MS. xviii + 283 pp.

Wilson, D.S. 1991. Estimates of survival for juvenile gopher tortoises, *Gopherus polyphemus*. J. Herpetol., 25: 376–379.

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Part VI
Biodiversity

Potential Implications of the Canadian *Species at Risk Act* on Oil and Gas Companies

Jason K. Smith

Pipeline companies operating in Canada are now faced with uncertainty over implications of the *Species at Risk Act* (*SARA*). Clauses 32 and 33 of the *SARA* prohibit the harm to or destruction of critical habitat of an extirpated, endangered or threatened species. Although *SARA* specifically applies to federal lands (only 5% of Canada's land base, excluding the Territories), patented and provincial Crown lands not protected through stewardship arrangements, conservation agreements or provincial or territorial laws may be affected by the SARA should the Minister deem that the critical habitat is not adequately protected. Mitigative measures to avoid or reduce adverse effects on listed species and plans to monitor the impact of the project will be essential in the pre- and post-construction phases of a project. Despite the *SARA's* intent to protect critical habitat through voluntary actions and stewardship programs, it affords pipeline companies the opportunity to compensate for the removal of critical habitat if it cannot be avoided. Companies must rely on due diligence as a part of their compliance plan. This manuscript explores the possible implications of this *Act* with respect to construction, operation and maintenance of oil and gas projects in Canada along with recent experience with permitting and constructing of pipelines in western Canada.

Keywords: Species at risk, critical habitat, compensation, pipelines, permits, stewardship

INTRODUCTION TO THE ACT

Oil and gas companies operating in Canada are now faced with uncertainty over the implications of the *Species at Risk Act* (*SARA* or the *Act*). Similar to the *Endangered Species Act* in the U.S., the *SARA* aims to protect wildlife at risk from becoming extinct or lost from the wild, with the ultimate objective of facilitating species recovery. Wildlife, as it pertains to the *Act*, has been broadly defined to include mammals, birds, plants, fish reptiles, amphibians, molluscs and insects. The federal government has included 233 species on the initial list in Schedule 1 (17 extirpated species, 105 endangered species, 68 threatened species and 43 species of special concern).[1] Since the *SARA* was passed in October 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed an additional 91 species as being at risk, making them eligible for addition to the *SARA* list (Government of Canada, 2002, 2003a,b).

There are seven key components of the *Act*. These include the following:

- Assessing and listing of species at risk by the COSEWIC. Listing is the prerequisite for protection under the *SARA*;
- Prohibiting the killing, harming or taking of an endangered, threatened or extirpated species or destruction of their residences (s. 32 and 33) as well as to possess, collect, buy, sell or trade an individual of a listed species or its part or derivative (s. 36). It is an offence to damage or destroy the residence of one or more individuals of a listed endangered or threatened species or of a listed extirpated species if

1 Extirpated – a wildlife species that no longer exists in the wild in Canada, but exists elsewhere in the wild.
Endangered – a wildlife species that is facing imminent extirpation or extinction.
Threatened – a wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern – a wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.

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a recovery strategy has recommended its reintroduction;

- Providing federal "safety nets" to allow for federal intervention on provincial or territorial governing bodies that fail to protect a species or its critical habitat;
- Developing recovery strategies and action plans for species at risk. A proposed recovery strategy must be prepared within one year of listing for an endangered species and within two years of the listing for a threatened or extirpated species with the exception of species on the initial list at the time Schedule 1 came into force on June 5, 2003. Action plans outline the specific measures required to implement the recovery strategy;
- Prohibition against destruction of critical habitat (s. 58) and the promotion of habitat stewardship and conservation through conservation agreements (s. 11). The prohibition may only apply once the critical habitat has been defined in the recovery strategy or action plan;
- Providing easy access for public participation through the online Public Registry. The public are invited to comment on various recovery strategies, action plans and other key documents; and
- Providing authority for compensation in relation to losses arising from the protection of designated critical habitats or residences of a species at risk. *SARA* allows for discretionary payment of "fair and reasonable" compensation as a result of any "extraordinary impact" of the habitat provisions.

In light of these and other provisions, the end result is an *Act* that is largely restricted to federal lands, aquatic species and migratory birds under the *Migratory Birds Convention Act*. Federal lands subject to the *SARA* include national parks, lands used by Department of National Defense, First Nation reserve lands and most of the land in the three territories. The *SARA* is administered by the ministers of Fisheries and Oceans, Canadian Heritage and Environment.

Stewardship and conservation agreements are intended to be the cornerstone of *SARA*, especially for protection of species at risk and habitat on provincial and private land. The federal government, provinces, organizations or landowners can enter into conservation agreements under the *Act*. Recently, the province of Saskatchewan entered into an agreement with the federal government to protect piping plover habitat at Lake Diefenbaker. The *Act* also provides flexibility for a wide range of agreements to be negotiated by the federal government, including the purchase of leases, easements, mineral rights, etc.

IMPLICATIONS

The *SARA* imposes restrictions on existing operations, and increases overall environmental work requirements and costs for new projects. Oil and gas projects that require a federal environmental assessment or National Energy Board (NEB) approval will have to focus more attention to the project's effects on listed species and their critical habitats. This is evident in the new NEB Filing Manual (2004), which requires proponents to consider the *SARA* in the environmental and socio-economic assessment and a recent amendment to the *Canadian Environmental Assessment Act* includes *SARA* listed species in it's definition of "environmental effects." Every Environmental Screening, Comprehensive Study or Joint Panel Review must take into account the project's effects on species listed in Schedule 1 of *SARA*.

Given the broad definition used to describe a species residence[2] it is unlikely that timing restrictions alone will alleviate any potential impacts on a species residence. Each individual species residence and critical habitat is different. Some species have more discrete, readily discernable habitat types, while others are vast and cover large areas. In Alberta, approximately, 70% of Alberta's listed species occur in the southern one third of the province, suggesting that projects in the native grasslands are more likely to encounter species at risk. It is expected to take up to 10 years before government resource managers have defined residences and critical habitat for all listed species in Canada. The focus is primarily on federal lands that are known to support listed species; otherwise it will be left up to the provincial governments and private agreements to protect residences and critical habitat of listed species.

The *SARA* provides new and easier mechanisms for interveners (e.g., environmental nongovernmental organizations) to challenge oil and gas projects. *SARA* has specific methods for people with concerns about a species at risk to become involved in the process. Pursuant to Clause 93, any person who is a resident of Canada and over 18 years of age may apply to the competent minister for an investigation of an alleged offence. Anyone who considers that there is an imminent threat to the survival of a wildlife species may apply to COSEWIC to assess the threat for the purpose of having the species listed as endangered on an emergency basis. Similar to the *U.S. Endangered Species Act*, the *SARA* could become a project opponent's most effective method to delay or potentially stop projects.

Despite *SARA*'s intent to protect residences and critical habitat for listed wildlife species, it does allow oil and gas companies to request a permit, enter into an agreement or obtain a license for an activity that would otherwise be a *SARA* offence. Clause 73 of the *SARA* was designed to ensure that competent ministers and other federal representatives take precaution in approving activities, which affect a listed species, its residence or its critical habitat. Typically, these agreements are reserved for scientific research, activities that

2 Residence – a dwelling place, such as a den, nest or other similar area or place that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating.

benefit the species and enhance its survival in the wild, or an activity whose effect on the listed species is incidental. Similar to Section 35(2) authorizations issued under the federal *Fisheries Act* for harmful, alteration or destruction, disruption of fish habitat at watercourses, these permits under *SARA* would likely require some form of compensation if mitigative measures are not sufficient to protect the species. To date no permits, licenses or agreements have been issued to an oil and gas company since the policies and guidelines for administering agreements, permits and licenses are still being developed.

Private and provincial Crown lands not protected through stewardship arrangements, conservation agreements or provincial or territorial laws could be subject to the "safety net" (s. 61), which allows the competent minister to make it an offence to destroy critical habitat in a province or territory. Some policy analysts feel this mechanism within the *Act* is discretionary and based on experience with other similar provisions in federal environmental law (e.g., *Clean Air Act*), unlikely to be implemented (Smallwood, 2003). There have been five pieces of environmental legislation enacted by the federal government that have all had similar "safety nets" and none to this day have ever been invoked (Boyd, 2004).

Contraventions of the *SARA* carry a wide variety of penalties depending upon the nature of the offence. Corporate directors and officers may also be convicted if they directed, authorized, or participated in contraventions under the *SARA* (s. 98) (Lindgren, 2001). Due diligence has been explicitly recognized as a defense under the *SARA* (s. 100), and a two year limitation period has been proposed (s. 107). Some companies believe that due diligence may be difficult to prove and in some cases may leave them wondering whether there was anything else they should have done to prevent harm. For all activities, companies should be aware of listed species that may be present in their project area, the types of habitat used by the species and the potential for adverse project related effects to these species. Most potential conflicts can be easily resolved through responsible environmental planning and operation protocols. In cases where *SARA* listed species may be affected by a project, companies need to consult with the appropriate authorities and obtain the necessary permits.

Complying with the *SARA* may:

- Create conflicts with project scheduling (e.g., delays to conduct wildlife and vegetation surveys, construction start-up);
- Increase costs associated with additional environmental surveys or potential delays to the construction schedule;
- Increase the potential for difficulty in dealing with landowners not aware of the regulations and unwilling to cooperate;
- Increase situations where there is inadequate time or less favorable seasons (i.e., winter) to conduct surveys;
- Entail costly mitigation measures that may be required to avoid impacts to listed species; and
- Involve requirements for pre- and post construction surveys.

COMPLIANCE PLANS

Many companies have or are developing compliance strategies to address the *SARA* for operations and maintenance activities as well as new projects. Companies should be encouraged to commence environmental reviews as early as possible to avoid project delays. Informational sources pertaining to listed species should be consulted and expert advice in determining whether a site is likely to support a listed species should be sought. Part of the compliance plan should include conducting wildlife and vegetation surveys where warranted. It is neither practical nor cost effective; however, to conduct these surveys on every site to be disturbed. In the event there is a high probability that a listed species may be present in the area, then a wildlife and/or vegetation survey should be undertaken. Furthermore, a series of programs should be administered that aim to educate field personnel about listed species as well as to notify private landowners and provincial authorities about potential species occurrences as part of a consultation program.

Case example #1

Roadways and pipelines result in both direct and indirect loss of woodland caribou habitat, a threatened species in Canada. Up to 85% of some caribou ranges in Alberta are within 250 m (270 yards) from a roadway or pipeline right-of-way. Specific oil and gas conservation measures applicable only to caribou ranges have been in place since 1996 and it is generally understood by companies that planning, time, and costs, will be higher to construct and operate facilities in these areas. Some specific caribou conservation measures include the following (Boreal Caribou Committee, 2001):

- The installation of telemetry to allow the facility to be operated remotely (*i.e.*, SCADA) once a well is in production;
- Constructing in the winter on frozen ground conditions to minimize the overall footprint or otherwise develop access that would be equivalent to frozen conditions, such as using matting with minimal grading;
- Coordination of access corridors with other resource users, including forestry, mining, recreation;
- Use of non-routine construction practices, such as restrictions on the length of time welded pipe can remain on the ground and the spacing of pipe segments to prevent physical barriers to caribou; and
- Public access control and worker awareness training programs, such as 24 hour manned gates and submittal of company specific caribou protection plans annually for government approval.

In Alberta, many oil and gas companies have participated in the Caribou Range Recovery Program, which started as an industry based initiative to improve reclamation of roadways and pipelines, and increase the availability of habitat in affected areas. This program has received support from the federal Habitat Stewardship Program, under the *SARA* (Government of Canada, 2003c). The program has allowed for the collection of more information on current status of reclamation on linear disturbances, experimentation with new reclamation strategies, development of a set of guidelines for reclamation of industrial developments, and development of a long-term monitoring strategy with the steering committees and the University of Alberta. A strategic planning component will be built into the project to assess recovery actions to supplement the *SARA* agenda.

Case example #2

There is continued uncertainty on the definition of "harass" under Clauses 32 and 33 of *SARA* when it comes to noise associated with construction and operations. A recent example of the implications of the *SARA* on a federally regulated pipeline arose in a federal government response to the recommendations of the National Energy Board/Canadian Environmental Assessment Agency Joint Review Panel Report prepared for the GSX Canada Pipeline Project (National Energy Board, 2003). The GSX Canada Pipeline Project was the Canadian portion of the project that involves the design, construction and operation of a natural gas pipeline from Sumas, Washington to a point on Vancouver Island, British Columbia. The Canadian portion of the project consists of approximately 44 km (70 mi) offshore and 16 km (26 mi) onshore of 406.4 mm (16 inch) natural gas pipeline originating at a point on the Canada-US border in the Georgia Strait to an interconnection on Vancouver Island. Georgia Strait, which was to be crossed by the marine pipeline, is frequented by the southern resident orcas (killer whales) that are listed as "endangered" under COSEWIC and are on Schedule I of the *SARA*. As per Clause 79 of the *SARA*, it requires those conducting environmental assessments under federal legislation to advise the competent minister immediately of any project likely to affect a listed wildlife species or its critical habitat.

Clause 79 of *SARA*, which came into force on June 5, 2003, creates a duty to notify the appropriate federal Ministers when a project is likely to affect a listed wildlife species. Further there is a duty to implement mitigation and monitoring measures to avoid or lessen such effects upon listed wildlife species. The Joint Panel recognizing Clause 79 of *SARA* and aware of public concerns on the issue, notified the Fisheries and Oceans Canada that a listed wildlife species may be affected by the GSX Project. Furthermore, the Joint Panel supported the precautionary principle.[3]

Despite the results of acoustic modeling studies conducted specifically for the project suggesting that the operation of the pipeline would not introduce noise frequencies that would be detectable by killer whales, the proponent was required to conduct post-construction assessments to conclude these findings. Furthermore, in the event the test results indicate that pipeline noise would be detectable to killer whales; additional mitigative measures would be required to reduce the noise level. Oil and gas companies may not only be required to carry out the necessary studies to document the presence or absence of listed species and the potential effects of the project, but in cases of uncertainty may likely be required to conduct pre- and post construction monitoring follow-up programs regardless of scientific knowledge.

CONCLUSION

Until the *SARA* regulations and/or guidelines are developed, it remains to be seen how the *Act*'s numerous discretionary provisions will be interpreted and implemented by federal ministries and officials. In some regards, oil and gas companies have been at the forefront of developing *SARA* compliance plans and habitat stewardship programs designed to allow for sustainable development in areas inhabited by listed species, while the federal government continues to focus on federal lands and looks to the provinces to develop management plans to protect species at risk. As the *Act* evolves, amendments to the *SARA* are inevitable and its implications will be decided in case law and litigation. To many companies, the implications of the *SARA* on provincially regulated pipelines is uncertain but unless the proposed project or existing project encounters areas likely to have high probability to encounter species at risk it will be "business as usual." However, one thing is for certain: "due diligence" is specifically recognized as a defense under *SARA* and, therefore, oil and gas companies and their management will continue to be responsible for how they carry out their activities.

REFERENCES

Douglas, K. 2002. Bill C-5: The *Species at Risk Act*, Legislative Summary. Law and Government Division, Library of Parliament. 43 pp.

Boyd, D. 2004. Species at Risk 2004 Conference. Presentation, Holistic health care for biodiversity: From preventative medicine to emergency wards.

Boreal Caribou Committee. 2001. Strategic Plan and Industrial Guidelines for Boreal Caribou Ranges in Northern Alberta. 35 pp.

3 Precautionary principle – if there are threats of serious or irreversible damage to a wildlife species, cost effective measures to prevent the reduction or loss of the species should not be postponed for lack of scientific uncertainty.

Government of Canada. 2002. *Species at Risk Act*.
Government of Canada. 2003a. *Species at Risk Act*, A Guide. 18 pp.
Government of Canada. 2003b. *Species at Risk Act*, Public Registry. Website: http://www.sararegistry.gc.ca.
Government of Canada. 2003c. Habitat Stewardship Program for Species at Risk Annual Report 2001–2002. 22 pp.
Lindgren, Richard D. 2001. The *Species at Risk Act*: An Overview. Canadian Environmental Law Association. 23 pp.
National Energy Board. 2003. Joint Review Panel Report GSX Canada Pipeline Project. 221 pp.
National Energy Board. 2004. NEB Filing Guidelines.
Smallwood, K. 2003. A Guide to Canada's *Species at Risk Act*. Sierra Legal Defense Fund. 71 pp.

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Research Gaps Regarding the Ecological Effects of Fragmentation Related to Transmission-Line Rights-of-Way

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For over 50 years, there has been extensive research conducted on the effect of transmission lines on the ecology of the local environment. A previous project was conducted to synthesize existing work into a summary of what is and is not known and to integrate that body of knowledge with a critical analysis from interviews with scientists involved in current research. The outcome of that effort was a comprehensive account of the "state of the science" on studies of ecosystem fragmentation related to transmission-line rights-of-way (ROW), and the effects of this fragmentation on species diversity and invasive species, particularly in Wisconsin. This paper, based on the larger effort, discusses the research gaps associated with fragmentation related to rights-of-way that were identified by reviewing over 700 articles and conducting in-depth interviews with 20 experts.

Keywords: Habitat fragmentation, Wisconsin, right-of-way, power line, right-of-way

INTRODUCTION

Scientists have produced hundreds of studies on the ecological effects of fragmentation related to transmission-line rights of-way (ROWs), with the results scattered among a variety of topics and publications. In a recent project, we compiled the research applicable to Wisconsin, and produced a systematic summary of the current state of the science and a critique of the research limitations, augmented by observations and commentary from scientists living and working in Wisconsin (Willyard et al., 2004). This paper is an outgrowth of that previous effort, but focuses on gaps in the research, most of which have broad applicability beyond Wisconsin. A modest amount of background information provides a context for discussing the research gaps, and the findings can serve as a guide for developing further research efforts that address the ecological effects of transmission-line ROWs.

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METHODS

The primary literature search was carried out during February 2004 using the Biological Abstracts database with the following five key phrases—edge effect(s), fragmentation, corridor(s), neotropical migrant(s), invasive species—in combination with the keyword Wisconsin and with the key phrase transmission line(s). Additional terms similar to transmission line were used to ensure a comprehensive search. Of the citations identified in the literature search, only those pertinent to Wisconsin were selected for review. Final inclusion or elimination was determined according to the following criteria:

- International studies were eliminated, with the exception of Canadian studies that were conducted in locations with species similar to those that exist in Wisconsin;
- In most cases, studies conducted in locations with species not found in Wisconsin were eliminated; and
- Some studies that did not appear in the primary literature search but were frequently cited in the articles reviewed were identified as particularly important and therefore were included.

Noted Wisconsin scientists provided information on their research efforts as well as a local perspective to the written literature. In total, 20 experts were identified and interviewed by telephone or in person from February 24 to June 7, 2004, using questions tailored to their area of expertise.

ECOLOGICAL EFFECTS OF FRAGMENTATION AND CORRIDORS

The ecological effects produced by linear ROWs can be grouped into two broad categories: fragmentation of habitat and creation of ROW corridors, both of which can have positive and negative consequences depending on the species in question. Although this paper focuses on the research gaps relating to fragmentation, these effects cannot be examined without considering the often profound impact of the corridor itself. It should be noted that the majority of the literature pertains to ROWs that pass through forested land because that type of landscape exhibits the most measurable effects.

Fragmentation

Human development activities can separate once-whole ecosystems into remnant patches divided by dissimilar habitat (Wilcove et al., 1986; Meffe et al., 2002). This is the ecological condition known as habitat fragmentation. This section examines three outcomes associated with habitat fragmentation related to transmission lines: (1) reduced habitat area, (2) species isolation, and (3) increased edge. These outcomes are discussed in the context of research limitations and gaps in the scientific knowledge.

Reduced-area effects

In addition to the direct ecological impact of habitat loss associated with a newly developed ROW, there can be deleterious effects from a reduction in the size of the remaining habitat patch, which can result in the loss of species that are area sensitive.

In the literature, the meaning of the term area sensitive has shifted over time. Previously, it encompassed any species that showed a direct relationship between patch area and probability of occurrence, without taking into account the driving factor behind the relationship (Robbins et al., 1989). As scientists have reached a better understanding of the mechanisms behind these relationships, the term area sensitive has come to refer specifically to species that require a large habitat area. Some species demonstrate species-area relationships that are actually due to an increase in the amount of habitat edge, not a decrease in area. Those species are now considered to be edge sensitive rather than area sensitive because they do not necessarily require large, continuous areas of habitat. Taken as a group, species exhibiting a relationship between area and probability of occurrence could more accurately be described as fragmentation sensitive, a broad descriptor encompassing both area sensitivity and edge sensitivity. Although there is still some confusion in the literature, the term area sensitive is used here to indicate species that respond to the actual size of the remnant patch. This genuine area sensitivity is often a characteristic of animals with a large body size, high placement on the food chain, or special ecological requirements (Temple, 1996).

In its current context, true area sensitivity is a complex concept. Not only is information limited on which species demonstrate a response to actual patch size, but the issue becomes more complicated when discussing area-sensitive species and transmission lines, because little information exists about species' perception of fragmentation. The gap between two areas of habitat separated by a transmission line is not large. Many species considered area sensitive may not necessarily perceive those two patches of habitat as separate entities; because they continue to use both sides, the area of their habitat is only reduced by the amount lost to the ROW. Intuitively, a gap such as a ROW should not affect the overall habitat area for wide-ranging, mobile species; however, for smaller terrestrial mammals or insects, a ROW may define the edge of a habitat patch. In general, it is likely that the number of plants and animals affected by reduced habitat area as the result of a ROW is limited, and largely unidentified in the literature.

Isolation effects

Another result of habitat fragmentation is that plants and animals in the remnant patches can become isolated. The reaction of any particular species to creation of a ROW differs and it is likely that many species, especially mobile ones, are tolerant of small habitat gaps and do not perceive a single ROW as a source of fragmentation or isolation. In general, crossovers on the ROW depend on the width of the gap, the species in question, and the habitat provided by the ROW. Nevertheless, for species that do become isolated, the consequences can be seen in both long- and short-term effects. Populations that become isolated, both physically and genetically, face an increased risk of extinction (MacArthur and Wilson, 1967). Additionally, if a habitat patch loses its population of a certain species, physical isolation may prevent new individuals from immigrating to colonize the patch and the species will become locally extinct. The absence in the literature of more than one study for any species—with the exception of deer and a few birds—makes it difficult to identify behavioral patterns. Very little research has been done on plants, insects, reptiles and amphibians—groups identified by the experts as being potentially sensitive to corridor-induced isolation.

Edge effects

Some species may be sensitive to edges and vulnerable to edge-associated pressures. Edge effects are possibly the most detrimental ecological outcome of the fragmentation caused by transmission-line ROWs. Creation of edge induces variations in microclimate, transformations in vegetation and animal life, and changes in biotic interactions (Watkins et al., 2003; Brisson et al., 1997; Chasko and Gates, 1982; Murcia, 1995; Waller, 2004). The direct effects related to changes in the microclimate lead to even more variation through indirect effects such as increases in deer populations, brood parasitism, and predation (Murcia, 1995). Some of the scientists interviewed emphasized that the effects of transmission-line ROWs could be more severe than some other types of edge-producing development because ROWs cover long distances and are more permanent than edges resulting from more temporary openings, such as clear cuts.

Although there is a sizeable quantity of research examining the effects of increased edge, a number of gaps still exist. One potential edge effect that has received little attention is the influence of humans (Meffe et al., 2002). Poachers, hunters, nature enthusiasts, birdwatchers, mountain bikers, and users of all-terrain vehicles find most transmission-line ROWs readily accessible, especially where the ROW bisects a road. The low-growing vegetation typically encountered makes it a desirable transit route and allows humans access to areas that might otherwise be relatively inaccessible.

In addition to human use, there is a paucity of research on the relationship between edge and non-avian species, non-forest habitats, and ecological processes other than predation and parasitism. Only a handful of studies exist and the results tell us very little about ecological trends for species such as reptiles, amphibians, mammals, and insects or for wetlands and other habitats. Despite these gaps; however, the literature suggests that edge effects related to fragmentation produced by ROWs are likely to have a negative impact on the greatest number of species.

Corridors

The land set aside for electric transmission lines creates ecological corridors—long ribbons of low-growing vegetation, often in contrast to the landscapes through which they pass. Corridors have two main effects: (1) they provide habitat for early successional or open area plants and animals and (2) they increase connectivity between habitat patches. Corridors can affect the surrounding landscape in both positive and negative ways, facilitating movement of rare or sensitive plants and animals in some cases, but also providing for the spread of unfavorable invasive species. The provision of early successional habitat and the entrance of invasive species into corridors are both significant, if not well-documented effects, and warrant further study.

Early successional habitat

Transmission-line ROW corridors create early successional habitat, characterized by a mixture of grasses, flowering plants, shrubs, and saplings, that can provide additional resources for birds (Confer and Pascoe, 2003; Askins, 1994), a variety of butterflies (Lanham and Nichols, 2002), rare plants (Sheridan and Penick, 2002), and amphibians (Yahner et al., 2001). The research conducted on the new habitat created by ROWs is limited. The species that use ROWs and the extent of the advantages or disadvantages found in a particular ROW depend on the vegetation and land management practices in the corridor and in the surrounding habitat. Results typically identify only the presence or abundance of a species and do not examine population trends.

Movement and connectivity

Creating ecological corridors for the movement of animals and, indirectly, plants between remnant habitat patches has been endorsed as a means of mitigating landscape fragmentation (Noss, 1991). Increased connectivity facilitates immigration between habitat patches (Temple, 1996) and dispersal through disturbed or otherwise unsuitable landscapes. It has been suggested, though not wholly accepted, that transmission-line ROWs can benefit a few specific species by providing dispersal routes (Schaefer, 2002). Ecological processes contributing to the spread and viability of plants can be affected by enhanced movement of organisms acting as pollinators or seed dispersers (Tewksbury et al., 2002). The increased movement is thought to promote genetic exchange and enhance population viability in plants and animals (Temple, 1996; Simberloff and Cox, 1987), thereby avoiding or reversing local extinction.

Evidence in support of the benefits of connectivity is species-specific and incomplete. For some ecologists and conservation biologists, sufficiently convincing data are lacking and they consider the effectiveness of ROWs as movement corridors an optimistic possibility at best.

Invasive species

While there are benefits associated with increased movement, there is also ample evidence that not all movement is beneficial. Scientists caution that possibly the most detrimental consequence of corridors is the facilitated spread of invasive and undesirable species into previously pristine areas (Csuti, 1991; Zink et al., 1995; Panetta and Hopkins, 1991). Invasive plants share characteristics that make them detrimental to native landscapes, including faster growth rates, efficient dispersal mechanisms, and tolerance of a wide range of conditions (Hoffman and Kearns, 1997). These plants are also at an advantage because they typically exist in the absence of natural enemies that would serve to limit their populations. The large edge-to-area ratio and construction and maintenance disturbances associated with ROWs create an ideal situation for the establishment of invasive plants.

The main limitation in the research regarding invasive species is the small number of studies and the disparity between the expert opinions and some of the published findings. Although the results of two studies found the effects of invasive plants on ROWs and in the adjacent habitat to be minimal (Rubino et al., 2002; Cameron et al., 1997), one of the experts stressed that open areas, such as ROWs, will always have higher densities of most exotics. In addition, long-term impacts of relatively new ROWs cannot yet be judged. Invasions often have a lag phase that can last a few decades before a species rapidly increases. Early stages of an invasion may not appear to be serious if only a few plants are involved; however, these can eventually grow rapidly when the population reaches its threshold (Waller, 2004).

CONCLUSIONS AND FUTURE RESEARCH

Transmission-line ROWs do not appear to have a broad ecological effect on groups of plants and animals. On the contrary, the effects seem to be species-specific and localized; a particular species may experience a limited effect, but that effect cannot be extrapolated to other species in other locations. ROWs have a relatively narrow width, and therefore are more likely to filter movement of animals, rather than completely block movement. Consequently, few species will be isolated or will perceive a reduction of their habitat area due to a ROW, although there may be substantial effects from increased edge.

In general, the literature presents three significant ecological effects of fragmentation that are relevant to transmission-line ROWs in Wisconsin: (1) creation of increased forest-edge habitat, (2) formation of early successional habitat, and (3) spread of invasive species.

The new edge habitat is a benefit to species that live in or use the habitat that exists in ROWs, such as deer, which profit from the browsing potential created by increased edge. In Wisconsin, this is not considered to be a positive outcome, particularly for the State's native plants already suffering from heavy deer browsing. Increased edge has also been associated with a decrease in forest songbirds in Wisconsin as a consequence of increased brood parasitism from brown-headed cowbirds and predation of songbird nests.

The creation of open and early successional habitat in a ROW is beneficial to species that thrive in this type of landscape. In Wisconsin, ROWs have a positive effect on the federally endangered Karner blue butterfly. Populations of this species have increased in open areas, such as managed ROWs, where blue lupine, a plant vital to the butterfly's survival, is increasing in abundance. The Karner blue butterfly thus serves as an example of a positive outcome of ROW corridors.

A negative result of the increased connectivity and movement afforded by a ROW is the potential for introduction of invasive species. For example, movement by animals along a ROW or human movement for management or recreational purposes can facilitate the spread of invasive species into previously inaccessible areas. This increased movement provides for the spread of damaging plants that monopolize ecosystems and compete with native vegetation, negatively affecting animals dependent on those habitats. The spread of invasive species is an issue of great concern to Wisconsin scientists.

RESEARCH GAPS

The published scientific literature on the ecological effects of fragmentation tends to be scattered and suffers from a number of identifiable research gaps. These become even more apparent when information provided by the interviews of Wisconsin scientists is combined with findings from the literature. The following section examines gaps related to the previously identified areas of study that are most relevant to the effects of transmission-line routing on the local ecology of Wisconsin.

Increased edge

The changes associated with construction of transmission-line ROWs include effects that vary in both magnitude and importance. In terms of overall impact relative to more intrusive landscape changes, the literature suggests that ROWs cannot be considered major factors in reduced habitat area or increased species isolation for a majority of plants and animals; however, they have a significant impact on increased habitat edge. Without a doubt, edge effects are the most significant ecological outcome of fragmentation resulting from ROW development. There are a number of possible topics for future investigation of the effects of increased edge habitat, as follows:

- ROW width and management: How do ROW width and vegetation management in the ROW affect rates of cowbird parasitism and predation? Are there ROW widths or management techniques that could minimize the negative impacts associated with edge and maximize positive habitat- or connectivity-related benefits for Wisconsin's endangered species, threatened species, and species of special concern? How do these outcomes associated with ROWs differ from other forms of landscape fragmentation?
- Predation rates: To what degree are different species affected by predation across the state? Does predation affect non-avian species? How does management of the ROW edge facilitate or inhibit predator movement?
- Cowbirds: Causal evidence between cowbird parasitism and declining avian populations is lacking for most species. Which population declines are predominantly related to high rates of parasitism? What are the geographical patterns of cowbird parasitism

in Wisconsin? How are amount of edge, regional cowbird densities, amount of forest interior, landscape configuration, and proximity to edge and cowbird feeding grounds related to parasitism rates?

- Source-sink dynamics: Are animals avoiding edge? Attracted to edge? Experiencing lower reproductive success along the edge? How do these patterns differ across the state? Where are species succeeding and which areas are sinks?
- Non-forest habitat: How are non-forest landscapes, such as wetlands, open areas, barrens, and prairies, affected by ROW edge?
- Human activity: How do edge-related human activities influence ecosystems?

Invasive species

The relationship of ROW corridors to connectivity and movement of invasive species in Wisconsin is not well-documented. Much of the concern regarding invasive species is a result of observations and anecdotal evidence.

- Construction and management of ROWs: Can ROWs be constructed and managed to maximize benefits and minimize adverse effects, particularly to species that are endangered, threatened, or of special concern in Wisconsin? What are the effects of vegetative composition and management (e.g., mowing, herbicide use) on facilitating or impeding movement of invasive species?
- Life history: How do invasive species differ in their ability to spread and colonize habitats?
- Human activity: What is the role of humans in the spread of invasive species along ROWs and can the spread be mitigated by management of access for leisure activities or by best construction practices?

Early successional habitat

Although the early successional habitat created by transmission-line ROW corridors generally is viewed as beneficial for some plants and animals in Wisconsin, there are limited data on the species that inhabit ROWs, especially those that are endangered, threatened, or of special concern, and whether or how they profit from this type of habitat.

- ROW species: What are the species that inhabit ROWs? Breed in ROWs?
- Source-sink dynamics: Does the narrow width of the ROW habitat make early successional species more susceptible to edge effects from the surrounding landscape? Do ROWs negatively affect some species by acting as ecological sinks?
- Management: How does management of a ROW affect which species reside there? Does ROW width affect a population's fitness or movement capabilities in ROW habitat?

Other gaps

The three preceding categories deserve attention because they represent the most significant ecological effects of transmission-line ROWs. There are gaps; however, in the research pertaining to the other ecological effects that merit consideration as well.

- Perception of fragmented habitat: What is the gap width at which key species lose their ability or willingness to cross?
- Connectivity and movement: Which species respond positively to connectivity? What ROW width or management practices are necessary to ensure that ROWs are used as movement corridors for species that are endangered, threatened, or of special concern? What is the risk of ROWs facilitating disease transmission and how can this risk be mitigated through management practices?
- Isolation: Which species, if any, are susceptible to isolation resulting from ROW-induced fragmentation? How can that isolation be mitigated through management or construction practices? How are isolated populations affected genetically?

Research limitations

Scientists strive for the ability to predict how transmission-line construction will affect different ecosystems. Once the effects are predictable, policymakers can evaluate cost-benefit analyses and energy providers can make management decisions. Regarding areas for further research, three limitations underscore all of the others.

First, due to the limited and immediate nature of scientific funding, many studies discussed in this paper and almost all the studies specific to ROWs are short-term and/or species-specific. In order to determine the effects of fragmentation related to ROWs, studies that examine more factors over longer periods of time are needed. Scientists must have an understanding of the baseline—the assemblage of species that existed in an area prior to construction disturbance—before they can conduct meaningful research that could establish a causal relationship. General trends can only be identified when studies examine a number of species over time. ROW-induced fragmentation may result in effects that are not perceived because they occur a long time after construction or they affect species that are not investigated because they are presumed to be unimportant in relation to local economic activity or conservation priorities. The most useful methodologies would measure the abundance and distribution of a variety of species in a site before construction of a transmission-line ROW and for a period of time after construction.

Second, the body of literature is insufficient to allow ecologists to predict how development activities will affect particular populations. There is not enough information about the distribution, abundance, reproductive and habitat requirements, and interactions of plants and animals. For example, some groups, particularly plants and insects, may be significantly affected by ROW-induced isolation; however, a lack of general ecological knowledge makes it difficult to identify the affected groups or individual species. In Wisconsin, field work on exotic plants, grassland birds, and the Karner blue butterfly in actual ROWs would be valuable.

Third, the majority of literature examining ecological effects of transmission lines is of little value to the ROW managers because it does not address, or only loosely addresses, the one aspect of transmission lines that can be controlled after construction—management. For example, in order for ROW management practices to be effective, information must be available to enable managers to balance positive and negative outcomes of fragmentation with the needs and values of the citizens of Wisconsin, including human access for recreation, economic development, conservation, preservation, restoration, and the continuing need for reliable and abundant electricity.

Because the public values both conservation of resources and access to reliable power, there is an impetus to study the ecological effects of transmission-line corridors and to make decisions that maximize positive ecological outcomes while minimizing adverse consequences. Transmission-line routing is a growing concern; therefore, policymakers, funding agencies, and energy providers have a vested interest in supporting research that will provide the most value. Establishing a broad framework of research goals is the first step.

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REFERENCES

Askins, R.A. 1994. Open corridors in a heavily forested landscape: impact on shrubland and forest-interior birds. Wildlife Society Bulletin, 22(2): 339–47.

Brisson, J., A. Meilleur, M.J. Fortin, and A. Bouchard. 1997. Edge effects on vegetation in rights-of-way. In: Williams JR, Goodrich-Mahoney JW, Wisniewski JR, Wisniewski J, editors. Proceedings of the sixth international symposium on environmental concerns in rights-of-way management. Feb 24–26, 1997, New Orleans, LA, USA. Oxford: Elsevier. p. 25–33.

Cameron, D.S., D.J. Leopold, and D.J. Raynal. 1997. Effect of landscape position on plant diversity and richness on electric transmission rights-of-way in New York State. Canadian Journal of Botany, 75(2): 242–51.

Chasko, G.C. and J.E. Gates. 1982. Avian habitat suitability along a transmission-line corridor in an oak-hickory forest region. Wildlife Monographs, 82: 1–41.

Confer, J.L. and S.M. Pascoe. 2003. Avian communities on utility rights-of-ways and other managed shrublands in the northeastern United States. Forest Ecology and Management, 185(1-2): 193–205.

Csuti, B. 1991. Conservation corridors: countering habitat fragmentation—introduction. In: Hudson WE, editor. Landscape linkages and biodiversity. Washington: Island Press. p. 81–90.

Hoffman, R. and K. Kearns. 1997. Wisconsin manual of control recommendations for ecologically invasive plants. Madison (WI): Wisconsin Department of Natural Resources. 9 p.

Lanham, J.D. and M.J. Nichols. 2002. Butterflies and skippers in utility rights-of-way in the upper piedmont of South Carolina. In: Goodrich-Mahoney JW, Mutrie DF, Guild CA, editors. Proceedings of the seventh international symposium on environmental concerns in rights-of-way management. Sep 9–13, 2000, Calgary, Alberta, Canada. Oxford: Elsevier. p. 337–43.

MacArthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton (NJ): Princeton University Press.

Meffe, G.K., L.A. Nielsen, R.L. Knight, and D.A. Schenborn. 2002. Chapter 8—Landscape Level Conservation. In: Ecosystem management—adaptive, community-based conservation. Washington: Island Press. p. 169–86.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution, 10: 58–62.

Noss, R.F. 1991. Landscape connectivity: different functions at different scales. In: Hudson WE, editor. Landscape linkages and biodiversity. Washington: Island Press. p. 27–39. ISBN: 1-55963-109-0.

Panetta, F.D. and A.J.M. Hopkins. 1991. Weeds in corridors: invasion and management. In: Nature Conservation 2: The Role of Corridors. Chipping Norton, NSW, Australia: Surrey Beatty & Sons Pty Ltd. p. 341–51.

Robbins, C.S., B.A. Dawson, and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds in the Middle Atlantic states. Wildlife Monographs, 103: 1–34.

Rubino, D.L., C.E. Williams, and W.J. Moriarity. 2002. Herbaceous layer contrast and alien plant occurrence in utility corridors and riparian forests of the Allegheny High Plateau. Journal of the Torrey Botanical Society, 129(2): 125–35.

Schaefer, V. 2002. Rights-of-way management in support of biological conservation. In: Goodrich-Mahoney JW, Mutrie DF, Guild CA, editors. Proceedings of the seventh international symposium on environmental concerns in rights-of-way management. Sep 9–13, 2000, Calgary, Alberta, Canada. Oxford: Elsevier. p. 303–7.

Sheridan, P.M. and N. Penick. 2002. Highway rights-of-way as rare plant restoration habitat in coastal Virginia. In: Goodrich-Mahoney JW, Mutrie DF, Guild CA, editors. Proceedings of the seventh international symposium on environmental concerns in rights-of-way management. Sep 9–13, 2000, Calgary, Alberta, Canada. Oxford: Elsevier. p. 185–91.

Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology, 1: 63–71.

Temple, S.A. 1996. Ecological principles, biodiversity, and the electric utility companies. Environmental Management, 20(6): 873–8.

Tewksbury, J.J., D.J. Levey, N.M. Haddad, S. Sargent, J.L. Orrock, A. Weldon, B.J. Danielson, J. Brinkerhoff, E.I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. Proceedings of the national academy of sciences of the United States of America, 99(20): 12923–6.

Waller, D. 2004. Department of Botany, University of Wisconsin-Madison. Interviewed on April 2.

Watkins, R.Z., J. Chen, J. Pickens, and K.D. Brosofske. 2003. Effects of forest roads on understory plants in a managed hardwood landscape. Conservation Biology, 17(2): 411–19.

Wilcove, D.S., C.H. McLellan, and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone. In: Soule ME, editor. Conservation biology—the science of scarcity and diversity. Sunderland, MA: Sinauer Associates, Inc. p. 237–56.

Willyard, C.J., S.M. Tikalsky, and P.A. Mullins. 2004. Ecological effects of fragmentation related to transmission-line rights-of-way: a review of the state of the science. Wisconsin Focus on Energy http://www.focusonenergy.com/page.jsp?pageId=1540 accessed Aug 18, 2004: 66 p.

Yahner, R.H., W.C. Bramble, and W.R. Byrnes. 2001. Response of amphibian and reptile populations to vegetation maintenance of an electric transmission line right-of-way. Journal of Arboriculture, 27(4): 215–21.

Zink, T.A., M.F. Allen, T.B. Heindl-Tenhunen, and E.B. Allen. 1995. The effect of a disturbance corridor on an ecological reserve. Restoration Ecology, 3(4): 304–10.

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Mitigation Measures for Rare Species During Necessary Maintenance Activities Within Existing Utility Rights-of-Way

Diana L. Walden, Stephen Morawski, and Ingeborg E. Hegemann

The northeastern United States is losing its open field habitat as old farms are either developed or abandoned, allowing reforestation to occur. The plant and wildlife species that require field habitat, or the biologically diverse edge habitat between field and forest, are increasingly observed on existing, cleared utility line rights-of-way (ROWs). Rare, threatened, and endangered species are often located in these corridors, specifically due to the disturbance generated habitat they provide. The initial installation of the utility created the habitat, which these species require; however, necessary maintenance and upgrade of utilities and utility corridors is coming under increased scrutiny from state natural heritage programs. This paper provides a number of case studies for state-listed vertebrate, invertebrate, and plant species identified in existing utility ROWs, and the various mitigation measures and plans developed to gain clearance from state agencies to perform the facility maintenance work. The case studies include relocation and subsequent monitoring of a wild garlic (*Allium canadense*) population within a New Hampshire wetland, post-construction survey and monitoring of a wild lupine (*Lupinis perennis*) population essential for the Karner blue butterfly (*Lycaeides melissa samuelis*) in New York, and wildlife barriers, visual transects and clearance activities for the eastern box turtle (*Terrapene carolina carolina*) and wood turtle (*Clemmys insculpta*) in Massachusetts. Within each case study, this paper will also examine the key aspects of the ROW habitat that attracts these species.

Keywords: Endangered, Karner blue butterfly, mitigation measures, pipeline, rights-of-way, state-listed, threatened, turtles, utility maintenance, wild lupine, wildlife habitat, right-of-way

HABITAT VALUE OF UTILITY RIGHTS-OF-WAY

The nature of both natural gas pipeline and electrical transmission rights-of-way (ROWs) require regular vegetative maintenance in order to create access and prevent damage to the facilities. Both types of utilities have restrictions on woody vegetation reaching specified heights on the corridors as extensive root systems could damage an underground pipeline's protective coatings, while branches could damage overhead wires. Due to this required maintenance, ROWs typically consist of scrub/shrub communities or grasses and forbs habitats, which are becoming increasingly scarce, especially in New England and the northeast. Suburban sprawl and development as well as natural reforestation of abandoned agricultural and farmed areas have eliminated much of the old field and thicket habitat, which was once common here (Askins, 2001). In New Hampshire for example, forest cover was approximately 47% of the land use in 1880 and had returned to 87% in 1980 (Litvaitis, 1993). The decline of early successional habitats is not as obvious to the general public as are the issues of deforestation or even loss of grasslands. The importance of this habitat type is not as well-known and people are not as familiar with the species that utilize it (Askins, 2001). Since it is expensive to maintain, restore or create shrublands and early successional areas, King (2002) suggests "taking advantage of human activities that inadvertently create" this habitat, such as ROWs.

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In our experience, the sounds and signs of wildlife are abundant when traversing a utility corridor. Red-tailed hawks (*Buteo jamaicensis*), wild turkeys (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianis*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), northern racer snakes (*Coluber constrictor*), eastern garter snakes (*Thamnopnis sirtalis sirtalis*), wood turtles,[1] eastern box turtles, spotted turtles (*Clemmys guttata*), blue spotted salamanders (*Ambystoma laterale*), and many other mammalian, amphibian and passerine species have been observed either directly or through tracks or scat during our inspections on corridors. Rather than causing detrimental fragmentation, which occurs with roadway construction, established, well-managed utility ROWs appear to actually create or enhance habitat for some species. As with all land uses that create edges, there is potential for negative edge effects, but edges between cover types are biologically diverse habitats, which often support more species than single cover types (Askins, 2001). Edges are most beneficial to wildlife when invasive species are prevented from becoming established, and when surrounding forested land is not heavily fragmented from other uses. The early successional habitat provided by ROWs is especially beneficial to a number of avian species (Yahner, 2003; King, 2002). Both wildlife and plant species that are state-listed rare, threatened and endangered are also becoming common on utility corridors, either because they rely on this type of habitat in decline everywhere else, or because features of the edge environment provide unique benefits or functions. Although established ROWs may actually provide the habitat that attracts rare species, utility companies must comply with all state and federal endangered species legislation in order to prevent takings. This entails developing appropriate and well-timed vegetative management in areas where rare species are known to occur along or adjacent to the corridors, as well as developing mitigation plans for necessary maintenance to the facilities in these areas.

NECESSARY MAINTENANCE AND CONSTRUCTION

In addition to regular vegetative maintenance, utility companies often need to access and temporarily disturb rights-of-way for physical maintenance to the facilities. For example, the Tennessee Gas Pipeline Company (TGP),[2] as well as other companies that provide natural gas to the public, are regulated by the U.S. Department of Transportation, and are required by law to protect their entire pipeline system from corrosion. They are therefore required to regularly perform internal and external surveys on the pipeline to ensure that the corrosion control measures are working correctly. When areas of poor coating or pipeline anomalies are identified, affected pipelines must be repaired in compliance with the Natural Gas Pipeline Safety Act and 40 CFR Part 192 – Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards. This requires excavation of the pipeline for evaluation and repair and in some cases, installation or replacement of anodes and remote ground bed structures meant to provide supplemental corrosion protection.

Electric transmission companies undertake required regular maintenance or upgrades of their facilities. Additionally, new construction results in activities that may affect rare species. Whenever maintenance work or new construction is required in an area identified as state-listed rare, threatened or endangered species habitat, utility companies must provide a mitigation plan and gain clearance from the appropriate state agency. In Massachusetts, the agency is the Massachusetts Natural Heritage and Endangered Species Program (NHESP) and in New Hampshire it is the New Hampshire Natural Heritage Inventory (NHNHI). New construction and maintenance also require consultation with the U.S. Fish and Wildlife Service (USFWS). These agencies require all plans to be reviewed and approved so as not to harm the species or the associated habitat.

This paper presents several case studies where utility ROWs provide habitat for rare species, both plant and wildlife. Most of our direct experience is centered around natural gas pipeline corridors, specifically TGP's system in the Northeast. Each study will look at the mitigation measures proposed to minimize any impacts to the species and habitat, the implementation of the measures, and the features offered by the corridor that may have attracted the species initially.

IDENTIFIED CASE STUDIES

The following case studies present general information on the type of construction required for each project site as well as the mitigation measures that were implemented to minimize impacts on the rare species habitat. Each project site was evaluated for at least 2 consecutive years following construction in order to determine the success of the mitigation and restoration efforts.

Wood turtle and eastern box turtle, Upton, Massachusetts

Warren Brook is a perennial stream that crosses the corridor of the TGP main 200 line in Upton, Massachusetts. The stream flows in a southerly direction across the ROW, which is approximately 50 feet wide in this location. In 2002, TGP identified 2 spots in this general area where poor coating was indicated and

1 The wood turtle is also identified as *Glyptemys insculpta*.
2 TGP is a subsidiary of El Paso Energy Corporation.

repairs were necessary. One area required several hundred linear feet of excavation within the corridor to the east of the stream, while the other required 100 linear feet of excavation to the west of the stream, almost adjacent to the bank. In both locations, the pipeline needed to be exposed and inspected. The original damaged coating had to be removed and then the pipe was re-wrapped in a protective coating to prevent future corrosion to the line. The pipeline typically is buried at a depth of 4–6 feet and TGP estimated a 25 to 30-foot-wide construction path during maintenance in order to accommodate the temporary soil stockpiles, the trench, and equipment movement. In compliance with TGP/El Paso's *Environmental Construction Plan* (ECP),[3] which is utilized whenever construction or maintenance is performed, erosion controls such as silt fence and staked straw bales were placed between the work and wetlands to prevent sedimentation. Stockpiles were segregated into topsoil and subsoil in order to retain the proper order of soil horizons when the trench is backfilled. Whenever work in wetlands occurred and the soil could not support the construction machinery appropriately, timber mats were used to provide stability and prevent damage to the substrate. When work was complete, the area was backfilled and returned to its original contours. The construction area was seeded and mulched with straw where applicable. In this case, both locations included some activity within wetlands, but mats were not required.

Habitat characteristics

Both of the maintenance locations were within an area associated with Warren Brook and designated by the NHESP as actual habitat of the wood turtle, a species of special concern in Massachusetts. The wood turtle is a member of Emydidae, the pond and box turtle family. Although it is considered one of the most terrestrial members of this family, this species is always associated with slow to moderate woodland perennial streams, usually with muddy, sandy, or gravelly substrate and undercut banks. Wood turtles usually remain within several hundred meters of the banks of their stream but may move linearly along the stream channel up to several kilometers or more (Compton et al., 2002). They use a variety of riparian and upland habitat for foraging, basking, migrating, and nesting. Warren Brook meets these habitat characteristics as it is approximately 6–8 feet wide and has a sandy and gravelly substrate, interspersed with soft, silty areas. Portions of the stream are forested while other portions flow through tangled, shrub/sapling thickets.

The habitat at the ROW crossing is more open, with a strip of low, riparian woody vegetation about 20–25 feet wide along the streambanks and a landowner maintained field to the west. The typical vegetation in the riparian area includes red maple (*Acer rubrum*) seedlings, speckled alder (*Alnus rugosa*), silky dogwood (*Cornus amomum*), tussock sedge (*Carex stricta*), fringed sedge (*Carex crinita*), and soft rush (*Juncus effusus*). Other forb and grass species observed in the western field and ROW include sensitive fern (*Onoclea sensibilis*), meadowsweet (*Spiraea alba*), steeplebush (*Spiraea tomentosa*), timothy grass (*Phleum pratense*), quack grass (*Agropyron repens*), barnyard grass (*Echinocloa crusgalli*), goldenrods (*Solidago spp.*), Queen Anne's lace (*Daucus carota*), white clover (*Trifolium repens*), Common plantain (*Plantago major*), and path rush (*Juncus tenuis*). In the work location to the east of the stream, the ROW consists of similar upland grass and forb species as well as emergent wetland vegetation such as wool grass (*Scirpus cyperinus*), spike rush (*Eleocharis obtusa*), fringed sedge, Joe-pye-weed (*Eupatoriadelphus maculata*), green bulrush (*Scirpus atrovirens*), reed canary grass (*Phalaris arundinacea*), jewelweed (*Impatiens capensis*), and arrow arum (*Peltandra virginica*). This portion of the ROW was last mowed in 2003 and is not to be mowed more than once every 3 years and not between April 15th and August 1st to avoid the most active season of the turtle.

A mature wood turtle had been observed near the western bank of Warren Brook in the spring of 2001, as well as the spring of 2002, during inspections on a restoration area, which was the result of additional TGP maintenance in 2000. The turtle was a mature male that measured approximately 6 inches long and 5 inches wide. The individual was identified in approximately the same location in both years, in a clearing adjacent to the ROW and approximately 50 feet from the stream. The clearing is bordered by forest canopy on the three remaining sides and is dominated by grasses and sensitive fern. The turtle was observed moving through the vegetation, likely basking and foraging in this area.

Proposed mitigation

Due to the designation of the area as actual habitat for state-listed species, TGP submitted a mitigation plan with best management practices to the NHESP for approval. In addition to the standard erosion and sediment controls set in the ECP, TGP stated that wildlife barriers (e.g., silt fence) would be installed and embedded along the limits of work within the designated habitat. Silt fence was chosen as a barrier because wood turtles climb well and could easily access an area surrounded by straw bales. The wildlife barriers would be regularly inspected and repaired or replaced as necessary. A pre-construction survey would be conducted by a qualified biologist (also serving as the environmental inspector) to inspect the proposed project site for the presence or evidence of wood turtles. The biologist would visually survey the area for turtles and/or emerging hatchlings, and evidence

3 The ECP was developed based on recommendations from the U.S. Army Corps of Engineers, the U.S. Department of Agriculture, the Natural Resources Conservation Service, and the Federal Energy Regulatory Commission (FERC).

Fig. 1. This mature male wood turtle was observed in 2001 and 2002 approximately 50 feet from the western bank of Warren Brook in a clearing adjacent to the pipeline right-of-way.

Fig. 2. Work area within the right-of-way, isolated from the surrounding habitat by a wildlife barrier in order to keep wood turtles from entering and potentially being harmed by the activities. (Photo taken by DLW in 2002.)

of nests (particularly in any exposed upland areas adjacent to the work areas). The surveys would be conducted prior to any clearing and ditching, and regularly through the work period. Any open excavation as well as the remainder of the disturbed area would be enclosed with a silt fence/wildlife barrier at the end of each day. The environmental inspector would also apply for a Scientific Collection Permit for reptiles and amphibians from the Massachusetts Division of Fisheries and Wildlife in order to legally handle any state-listed species. In the event that a turtle (adult or hatchling) is encountered, the environmental inspector would hand-capture the turtle, document the finding (complete a rare species observation form) and relocate the turtle outside of the work area, away from any access road crossings. If a nest is found, it would be encircled with a silt fence, and the NHESP would be contacted for further direction.

The NHESP approved this plan and agreed that the work was not likely to have adverse impacts on wood turtles or associated habitat when these measures were implemented. NHESP also included the conditions that a native seed mix be used in any upland area within the estimated habitat and a wetland seed mix be used in the wetlands during restoration activities. A monitoring report was also required within one growing season of the completion of construction. The work was performed in late summer/early fall 2002, following all conditions in the approved mitigation plan. Prior to any construction we surveyed the entire work area, walking transects and performing visual inspection for any turtles. We repeated this process following the installation of the wildlife barriers to ensure that no individuals had been trapped within the work area before actual excavation began. At the end of each day, the contractor removed machinery from wetland areas and pulled silt fence back across the entrance to the work area. Although we performed several more visual surveys during the two to three week period of construction, no individuals were identified within or adjacent to the work area. The area was restored and reseeded and the barriers were removed, leaving straw bales in place until stabilization could occur.

Results

During July of 2003, we returned to the site to perform the monitoring required by NHESP. Vegetative cover was growing well in the wetland areas but remained slightly sparse in the sandier upland areas. Invasive species such as *Phragmites australis* and purple loosestrife (*Lythrum salicaria*) were present; however, the extent and locations of the species following the maintenance were not noticeably different from what existed prior to the work. No erosion, gullying, or sedimentation problems were noted on the slopes or stream banks at the sites. While wood turtles were not observed during this inspection, an eastern box turtle was seen crossing the ROW near the maintenance site to the east of Warren Brook. The individual was a mature male, approximately 6.5 inches long and 5 inches wide, and was observed in the more upland grass and forb cover described above. This area had not previously been identified with the NHESP as box turtle habitat and this observation may offer more information about habitats this species utilizes. The eastern box turtle is the most terrestrial of the Emydidae family and use wetlands as juveniles, or as refuge from hot weather as adults (MNHESP, 1994). The species can be found in woodlands, shrubby pastures, thickets, marshes and bogs, and along stream banks. The box turtle typically remains in a specific home range of approximately 1¼ acres, although some can be more transient. The authors documented the observation of the turtle as part of the NHESP reporting.

After 2 years of study on a ROW in Pennsylvania, Yahner et al. (2001) found that amphibian and reptile

Fig. 3. The ROW in which a male eastern box turtle was observed crossing during the year following the construction activities. This area had not been previously identified as box turtle habitat. (Photo taken by DLW in 2003.)

diversity was higher in the regular maintained, low vegetative growth ROW than in the adjacent forest. He observed an eastern box turtle in the ROW habitat on 3 separate occasions in comparison to no sightings in the forest. The MNHESP (1994) fact sheet for the box turtle also states that regenerating and selectively cut areas within woodlands may be important to the success of this species. Several studies imply that the wood turtle may actually be most successful in an edge habitat where a variety of habitats provide different food sources and where forest cover is adjacent to basking sites in open fields or clearings. Kaufmann (1992) rarely observed wood turtles solely in unbroken tracts of forest or large open pastures, but found the highest population densities in areas where a variety of habitats existed. Compton et al. (2002) also noticed this trend and concluded that the wood turtles choose forest edges and fragmented forests to balance their foraging and thermoregulatory activities. This information from various published sources, as well as the authors' direct observations of several turtle species, lend support to the idea that the wood turtle and the eastern box turtle are utilizing and actually benefiting from the habitat that the ROW offers adjacent to the forested stream and the woodlands.

Wild garlic and an exemplary floodplain natural community, Pelham, NH

In 2002, TGP identified the need to repair an existing remote ground bed located adjacent to the Concord pipeline lateral in Pelham, New Hampshire. Remote ground beds are located perpendicular to the pipeline corridor and consist of an impressed current, which uses rectified alternating current power and buried anodes to provide supplemental corrosion protection to larger areas of the ROW. The ground bed had not been repaired since its installation 30 years ago and the buried anodes needed to be replaced/replenished in order to continue to provide adequate protection to the pipeline. In addition, TGP intended to remove the existing wooden utility poles that had carried overhead cable, and to alternatively place the cable underground with the anodes. The remote ground bed is located in a forested swamp associated with a perennial stream, Beaver Brook. The poles were placed along a slightly bermed area that traversed the floodplain. Again, all work was performed in compliance with the best management practices stated in the ECP with appropriate erosion and sedimentation controls. Slight clearing was necessary within the forest in order to access the ground bed and the smallest machinery feasible was used to perform the construction. The poles were cut and removed from the wetland and the old buried anodes were excavated and replaced along with the cable. The work resulted in approximately 13,500 square feet (slightly less than 1,000 linear feet) of temporary disturbance within the wetland habitat. Timber mats were necessary for access in some portions of the site due to a soft muck substrate.

Habitat characteristics

From correspondence with NHNHI, we learned the area was designated as an exemplary floodplain natural community, which contained 3 state-listed plant species. It was identified as a southern New England floodplain forest characterized by the presence of swamp white oak (*Quercus bicolor*) and river birch (*Betula nigra*). The 3 listed species of concern included the river birch, and the herbaceous species of bulbous bitter-cress (*Cardamine bulbosa*) and wild garlic (*Allium canadense*). The dominant canopy layer in this area consists of red maple, swamp white oak and river birch, while the shrub layer is dominated by northern arrow-wood (*Viburnum dentatum*), highbush blueberry (*Vaccinium corymbosum*), and speckled alder. The herbaceous layer includes tussock sedge, sensitive fern, poison ivy (*Toxicodendron radicans*), royal fern (*Osmunda regalis*), and false nettle. Obvious hydrology and topography features indicate that the area regularly floods and forms pools of standing water. The substrate consists of a histosol, or dark organic soil greater than 16 inches deep, and some areas were saturated to the surface. Several areas were also slightly elevated, forming small mounds or microhabitats above the most saturated portions. The mounded, slightly elevated areas consisted of natural, dark loam and may have been created by the installation of the ground bed and movement of soil several decades ago. Some areas may have been created by the natural hydrology of the floodplain. The ground bed corridor retains a fairly strong canopy cover, but it allows additional filtered light and creates an area of slightly higher elevation. TGP hand-cuts woody vegetation within this easement when the adjacent ROW is mowed. The ROW is not to

Fig. 4. Wild garlic individuals were flagged and marked in groups in order to determine which were transplants and which remained in original locations. This assisted in identifying whether the relocation was successful. (Photo taken by DLW in 2003.)

be mowed more than once every 3 years and not between April 15th and August 1st.

As part of the Wetlands and Non-site Specific Permit issued from the New Hampshire Department of Environmental Services (NHDES) Wetlands Bureau, we were required to contract a qualified botanist to participate with the survey of the area and the identification of the rare species. With the assistance of Dr. Leonard Lord,[4] we performed a visual survey of the area and identified both mature and sapling river birch adjacent to the remote ground bed corridor as well as wild garlic in and adjacent to the proposed work area. No bulbous bittercress was observed. It was determined that any impact to the river birch individuals could be avoided with careful placement of machinery and construction activities. The wild garlic; however, was located directly within the ground bed ROW in several spots. Other individuals were located in some areas off the corridor; however, the species seemed to prefer the slightly elevated, mounded areas out of direct saturation. In our survey, we identified and recorded the reproductive stems of the population in 3 groups based on their location within the project site, identified as Groups 1, 2 and 3. We flagged and marked the individuals as we found them in order to facilitate relocation efforts. Wild garlic reproduces both through the bulblets formed from its inflorescence as well as underground perennial bulbs. Typical habitat includes floodplain forests/forested wetlands, alluvial soils by streams, and meadows and thickets (Maine DOC, 2004).

Proposed mitigation

Following the identification of the species of concern within the work area, the permit conditions required that a mitigation plan be submitted to the NHDES Wetlands Bureau and the NHNHI for approval. With Dr. Lord's assistance, we developed a plan to transplant the affected wild garlic from the corridor to similar microhabitats that supported wild garlic individuals. We would perform the relocation during the late summer when the plants were dying back and their dormant bulbs could be collected and replanted. The river birch individuals would be flagged for protection and an orange safety fence would be placed to indicate the limits of work to keep the machinery from entering the wild garlic habitat. NHDES and NHNHI approved the plan and the wild garlic was transplanted in late August 2002, under the direction of Dr. Lord. By this time, the stems and bulblets of the plants were still weakly attached and we used them (and the previously placed flags) to identify where the underground bulbs were located. The bulbs of any individual, which appeared to be in an area to be affected by the proposed maintenance, were excavated and transplanted under several inches of soil. We found that the bulbs tended to occur within 2–3 inches of the soil surface, and we attempted to recreate this condition during the transplant. We scattered the bulblets and "mulched" the area with natural leaf litter to mimic the natural dispersal patterns. Bulbs and bulblets from clusters of plants were kept near each other in the relocation process and were identified with corresponding flags. Alternate color flagging was tied on the ground flags to indicate transplants, while as many individuals as possible were left in their original locations. A total of approximately 250 bulbs and 320 bulblets were collected from the 3 groups and placed in the chosen transplant areas. The maintenance work took place during several weeks in September 2002 following all conditions in the approved mitigation plan. Prior to construction we met with the contractor to discuss the permit conditions and the presence of the species of special concern. The contractor established orange safety fence around the wild garlic and river birch individuals and was instructed to treat these as "no activity" areas. The work was performed as proposed and the area was restored and reseeded, leaving straw bales and mulch in place until stabilization could occur.

Results

During June of 2003, we returned to the site to perform the final monitoring required by NHDES. Vegetative cover was returning well and no erosion, gullying, or sedimentation issues were noted at the site. The wild garlic typically is at its peak growth in late May to late June so we chose this time to evaluate the success of the relocation efforts. Almost all of the flagged areas included individual plants and the majority had reproductive stems with new bulblets forming. We also observed that individuals continued to grow within the ground bed corridor in approximately the same

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Table 1. The total number of reproductive stems observed in each of the three groups in pre-construction conditions as well as the two years following construction

Group #	Reproductive stems pre-construction 2002	Reproductive stems 2003	Reproductive stems 2004
1	106	50	66
2	49	42	67
3	64	49	110
Total	219	141	243

Note: These totals include the reproductive stems in the corridor adjacent to the appropriate group.

locations that they had prior to construction disturbance and relocation efforts. Approximately 70% of the original number of reproductive stems was observed during the 2003 monitoring, indicating that the population was minimally affected by the maintenance activities and will continue to succeed. We also noted that the transplanted bulbs seemed to have more success at re-growth than areas where bulblets alone had been scattered.

We also returned in June of 2004 to monitor the population and collect further data on the relocation efforts. The numbers of reproductive stems, as well as smaller non-producing stems, seemed to increase dramatically, especially in the area of Group 3 where many of the bulbs and bulblets were transplanted. The number of individuals returning to the corridor was also significantly higher than in 2003. The total number of reproductive stems has actually exceeded the original population by 11% (243 stems in 2004 vs. 219 in 2002 post-construction). The following Table 1 presents the results of the survey prior to construction activities and the two years following construction. The quantities represent the number of reproductive stems, or those containing bulblets, in each of the 3 groups. Although there were many non-reproductive stems in each of the groups, they are not expressed in these data.

Table 2 is included to demonstrate that reproductive stems have returned to the disturbed ground bed ROW since the completion of the maintenance activities. Again, this count includes only the reproductive stems even though a number of non-producing stems were located in the corridor. Between the first (2003) and second (2004) year following construction, the total number of reproductive stems in the corridor had increased by over 400% (12 stems vs. 50 stems).

These observations indicate that the wild garlic population has not been negatively affected by the maintenance activities. The relocation efforts appear to have been successful in maintaining the population and the disturbance may have actually improved the habitat within the corridor. It is possible the construction removed species that were competing for light and space, allowing the wild garlic to increase. The distribution; however, has also changed with a smaller number of individuals located in Group 1 (which previously was the most populous of the groups) to a

Table 2. The number of reproductive stems observed in the ground bed corridor following construction and relocation

Group #	Reproductive stems in groundbed corridor 2003	Reproductive stems in groundbed corridor 2004
1	5	26
2	3	19
3	4	5
Total	12	50

higher number in Group 3. Overall, it appears the original construction of the remote ground bed may be the major factor in the success of the wild garlic in this area. All individuals were found clustered within approximately 50 feet of the corridor in our original survey, and nowhere else within this portion of the floodplain forest. Again, this may be due to the fact that the ground bed provided a slight elevation separation from the saturated surface of the wetland, as well as a slightly more open corridor through the forest.

Wild lupine and Karner blue butterfly, Bethlehem, NY

In early 2000, TGP was in the process of permitting several miles of new pipeline, identified as the Niagara Mohawk Lateral in Bethlehem, New York. The work included clearing a new ROW and miles of excavation to install new pipe. In addition to other environmental and siting permits required, TGP consulted with the USFWS as well as the New York Department of Environmental Conservation (DEC) in order to determine whether there were State or federally listed rare, threatened, and endangered species. A portion of the proposed ROW was in the vicinity of previous sightings of the Karner blue butterfly (*Lycaeides melissa samuelis*), a federally endangered species. A small patch of wild lupine (*Lupinis perennis*) was also known to occur near the proposed route, which could provide potential habitat for the Karner blue. Wild lupine is integral to the life cycle of this butterfly because it is the only known food source for the larvae. USFWS approved the construction project provided that the lupine patch was marked off with a perimeter avoidance-fence including a 20-foot buffer from the plants closest to the ROW. USFWS limited mowing within the fenced area to occur between October 1st and April 1st to avoid interference with the seeding of the lupine and nectar sources. In addition, minimum mowing height was set at 8 inches. Maintenance activities were to be scheduled outside of the typical timeframe of the flights of the adult Karner blue butterflies. USFWS also required 3 subsequent years of monitoring following completion of the construction.

The lupine patch is located on a small hillside or knoll within a narrow strip of trees and denser vegetation that separates the pipeline route from an electrical transmission corridor. Lupine typically requires dry, sandy areas in open woods or clearings. The study population covered an area of approximately 5,600 square feet. The hill was partially forested with oak (*Quercus spp.*) and other deciduous hardwoods. The surrounding flowering forb species included ox-eye daisy (*Chrysanthemum leucanthemum*), daisy fleabane (*Erigeron annuus*), field mustard (*Brassica rapa*), goldenrod species, black-eyed Susan (*Rudbeckia serotina*), red clover (*Trifolium pretense*), and Queen Anne's lace. With the combination of 2 utility corridors and surrounding agricultural uses, including a Christmas tree farm, the entire area consists of fairly open habitat. Evidence of all-terrain vehicle use and access from surrounding land uses was apparent here.

Monitoring the lupine population

Starting in the summer of 2001, we performed 3 years of official monitoring on the identified patch of wild lupine, and returned in 2004 to collect one more year of data. We planned on 2 visits per summer, attempting to time them during the 2 separate flight generations of the adults. The first occurred in late May to mid-June while the second occurred from mid-July to early August (NYDEC, 2003). During the original survey, we set up 4 transects beginning at the perimeter avoidance fence and running perpendicular into the field. The transects were fairly evenly spaced along the habitat area. Three of the transects were 81 feet long while the fourth was 54 feet to accommodate a change in the landscape. Each of the transects had 4 plots, evenly spaced along the transects. We also set up 2 off-transect plots to capture some of the highest density lupine patches, which had been missed by the transect locations. During the first visit of each year, we went to each plot and counted the total stems and stems with fruiting structures. We also estimated the numbers of clusters of plants as well as the percent cover at each plot. While counting lupine in the plots, we also examined the stems and leaves for predation, or signs of eggs or larvae. Following the lupine count, we performed three walking surveys along each transect line, waiting 20 minutes between each and flushing out any butterflies in the area. In the second visit of each year, we examined the lupine for signs of predation or eggs and perform the walking surveys for adult butterflies.

Fig. 5. Wild lupine is the only known food source for the larvae of the Karner blue butterfly. These lupine plants are transitioning between blooming and fruiting. (Photo taken by DLW in 2003.)

Results

The lupine is densely clustered in some areas of the site but completely absent in others. Every year, the study area appeared to demonstrate an overall increase in the amount of wild lupine plants. It is important to note; however, that in each year of the study, some of the original plots had to be re-established due to loss of staking or flagging, which may have altered the stem count slightly. Regardless, the number of stems as well as fruiting structures increased during our study. A slight drop in the count and average percent cover within the plots occurred from 2003 (14.9% cover) to 2004 (12.8% cover), but areas outside the transects appeared to be about as densely populated with lupine as the previous year, and significant new growth of plants/seedlings had occurred in the area of the transect with the most open and sandy habitat. Other areas where lupine did not establish itself, had a thick cover of grasses, which would likely be difficult to out compete for space and other resources. The following Table 3 presents the data in terms of the total number of stems present in each plot surveyed over the course of 4 years. The table also shows the number of reproductive stems in each plot. Almost 60% of all stems surveyed were considered to be reproductive.

During our survey, we observed the Eastern black swallowtail (*Papilio polyxenes*), the viceroy (*Limentis archippus*), the wood nymph (*Cercyonis pegala*), the mustard white (*Pieris napi*), and an Eastern tailed blue (*Everes comyntas*), but we were not able to observe a Karner blue during any of the years. We also did not identify any eggs or chrysalis on the lupine, although an unidentified larvae utilized and predated the lupine each year of survey. We consulted the literature and although the predation did not appear to be from Karner blue larvae, we have not completely dismissed the possibility.

Table 3. The number of total stems and reproductive stems within each survey plot over a four-year period

	Total stems				Stems with fruiting structures			
	2001	2002	2003	2004	2001	2002	2003	2004
1 Plot A	0	0	0	0	0	0	0	0
1 Plot B	0	0	0	0	0	0	0	0
1 Plot C	0	0	0	0	0	0	0	0
1 Plot D	0	0	0	0	0	0	0	0
2 Plot A	0	0	1	0	0	0	0	0
2 Plot B	27	33	74	55	5	30	32	27
2 Plot C	0	0	0	0	0	0	0	0
2 Plot D	0	0	0	0	0	0	0	0
3 Plot A	0	0	0	0	0	0	0	0
3 Plot B	0	41	46	41	0	21	43	27
3 Plot C	0	3	0	0	0	0	0	0
3 Plot D	0	0	0	0	0	0	0	0
4 Plot A	0	0	0	0	0	0	0	0
4 Plot B	0	0	5	16	0	0	0	0
4 Plot C	0	4	2	11	0	0	0	4
4 Plot D	0	0	0	0	0	0	0	0
Plot 1 Off-Transect	22	52	86	71	19	49	48	46
Plot 2 Off-Transect	21	102	109	110	13	101	93	72

The Karner blue butterfly is a species associated with open areas such as pine barrens and habitats affected and managed by regular wildfires. The loss of these open habitats and the prevention of natural fire has reduced the occurrence of wild lupine and therefore the butterfly, which relies on this plant (NYDEC, 2003). While not optimal, the open, regularly mowed or maintained habitat of a utility corridor may provide some refuge for these species. Although we did not observe any Karner blue activities during our inspections, we were basing our visits on post-construction monitoring and not a true scientific study or survey. A study would require many more days of surveying during each adult flight period, which may result in observations of individuals. Although Karner blue butterflies were not observed, potential valuable habitat is present in this location, with a small but successful lupine population on a sheltered knoll with adjacent large, maintained fields and open areas of the corridors, and a number of other nectar sources for adult butterflies.

CONCLUSIONS

The case studies all provide evidence that the disturbance associated with the necessary maintenance of utility infrastructure had no impact on the habitat for each of the monitored species. Appropriate mitigation techniques do protect the existing populations or individuals when correctly implemented. In the case of Warren Brook, a second turtle species of special concern was observed in the corridor following the completion of the pipeline repair work. The habitat provided by the corridor continued to be utilized by turtle species and there were no direct impacts to any individuals during the work. In the wild garlic study, we found the total reproductive portion of the population to increase in size by approximately 11% by the third survey year. This growth occurred following the maintenance disturbance and relocation efforts. Since these plants have already returned to the disturbed portion of the corridor, it seems that the work had no impact on the available habitat. The final study also demonstrated that the total number of wild lupine stems, as well as the reproductive portion of the population, has increased over the several-year survey. The introduction of the new pipeline ROW did not have an impact on the wild lupine stand and provides additional habitat beneficial to nectar sources for the Karner blue butterfly.

In addition to the case studies provided, we encountered a wood turtle foraging in another portion of a pipeline ROW in Massachusetts, in an area with a forested stream flowing parallel to the corridor. We observed a spotted turtle in Massachusetts within a small stream and wet meadow crossing a ROW. Several eastern box turtles were identified in or adjacent to a pipeline corridor in Connecticut where upland forests blended into wooded swamps or emergent marshes. We also observed a number of blue spotted salamanders under wooden planks in the middle of an electrical transmission ROW in a wet meadow habitat. The individuals were located hundreds of feet from the continuous forest habitat bordering one side of the field and corridor. This finding seemed to contradict the typical forested upland habitat that adult and juvenile mole salamanders are likely to prefer. All of these species are considered to be of special concern and were observed utilizing the habitat the utility corridors provided. Yahner et al. (2001) had also observed 8 different reptile and amphibian species within the border zones and wire zones of an electrical transmission ROW, including 2 salamander species under cover boards placed for the study. The salamander species were also observed in the adjacent forest but every other species was found exclusively in the ROW. The study suggests that all powerline corridors be maintained with border zones and wire zones of varying vegetative cover heights to provide maximum habitat types (Yahner et al., 2001). King and Byers (2002) found that powerline ROWs are actually successful nesting habitats for passerine species, which are not as affected by the negative predation and parasitic edge effects as previously thought.

Although ROWs and utility corridors often have negative connotations with the public and even government environmental agencies, the scientific literature is beginning to express the potential value of this land use for habitat for many types of plants and wildlife, some of which are species of special concern. The purpose of this paper is to demonstrate the number of personal observations of wildlife, especially state-listed species that we have experienced while walking or surveying ROWs. In our opinion, the habitat created by the presence of the corridor actually benefits many of these rare species when the proper location and construction methods are used. Timing and type of vegetative management also plays a critical role in the success of the habitat, as well as preventing establishment of invasive species. We also intended to convey that certain types of necessary maintenance can occur on rights-of-way in areas of estimated rare species habitat with no obvious impacts to the population. Our case studies demonstrate that implementation of the appropriate mitigation measures can be successful in preserving the existing habitat and protecting target species populations. We acknowledge that many factors affect the value of the potential habitat of utility corridors, and that our observations offer a general overview. Although our studies were limited to specific sites and time periods in the context of particular surrounding land uses, our findings provide the impetus for further investigation and evaluation of the effects of mitigation for species of special concern on pipeline and other ROWs.

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REFERENCES

Askins, Robert A. 2001. Sustaining biological diversity in early successional communities: The challenge of maintaining unpopular habitats. Wildlife Society Bulletin, 29(2): 407–412.

Compton, B.W., J.M. Rhymer, and M. McCollough. 2002. Habitat selection by wood turtles (*Clemmys insculpta*): An application of paired logistic regression. Ecology, 83(3): 833–843.

Kaufmann, John H. 1992. Habitat use of wood turtles in central Pennsylvania. Journal of Herpetology, 26(3): 315–321.

King, David I. and Bruce E. Byers. 2002. An evaluation of powerline rights-of-way as habitat for early successional shrubland birds. Wildlife Society Bulletin. 30(3): 868–874.

Litvaitis, John A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology, 7(4): 866–873.

Maine Department of Conservation Natural Areas Program. 2004. Wild garlic fact sheet.

Massachusetts Natural Heritage and Endangered Species Program. 1994. Eastern box turtle fact sheet.

New York State Department of Environmental Conservation. 2003. Karner blue butterfly fact sheet.

Yahner, Richard H., Russell J. Hutnik, and Stephen A. Liscinsky. 2003. Long term trends in bird populations on an electric transmission right-of-way. Journal of Arboriculture. 29(3): 156–164.

Yahner, Richard H., William C. Bramble, and W. Richard Byrnes. 2001. Response of amphibian and reptile populations to vegetation maintenance of an electric transmission line right-of-way. Journal of Arboriculture, 27(4): 215–221.

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Transmission Line Rights-of-Way as Enemy-Reduced Space for Moths (Lepidoptera)

Dylan Parry, George H. Boettner, and Jennifer A. Selfridge

Management practices that maintain habitats in an early successional stage are beneficial for a number of species of butterflies and moths (Lepidoptera). These benefits have been viewed primarily as enhancement of habitat for larval host plants and/or nectar sources used by adults. The potential for habitat management to alter interactions between Lepidoptera and their natural enemies is an aspect not previously addressed. Such amendment may enhance larval survival by disrupting the foraging behaviors of natural enemies. Of particular interest are the effects of vegetation management on an abundant and important invasive species, the exotic tachinid (Diptera) parasitoid *Compsilura concinnata*. This species has been implicated in the population declines of several native Lepidoptera. To quantify this potential effect, we focused on three species of moths on an electrical transmission line running adjacent to and through Cape Cod National Seashore, MA. Two of the species, barrens buck moth (*Hemileuca maia*) and yellow-necked caterpillar (*Datana ministra*), have suffered substantive population declines in New England in recent years and were more abundant in rights-of-way (ROW) habitat than in any other habitat assessed in the study area. We quantified mortality from *C. concinnata* in experimental populations of these species, and a third species *Antheraea polyphemus* deployed on open growing young oaks on a managed electric transmission line ROW and on the same host plants in adjoining mature forest. Parasitism of all three species was significantly reduced within the ROW habitat. The patchy nature of the early successional habitat, characteristic of managed ROW, may disrupt the search efficiency of this parasitoid, creating enemy-reduced space for these species of Lepidoptera.

Keywords: Pine barrens, early successional, *Compsilura concinnata*, parasitoids, non-target species, natural enemies, right-of-way

INTRODUCTION

In a seeming paradox, some threatened Lepidoptera (butterflies and moths) are abundant in habitats where anthropogenic disturbances are frequent and are rare in less disturbed sites. Decades of fire suppression may underlie declining populations of at least some of these species. Fire is thought to have maintained prairie, savannah, and barrens habitats in early successional states and the prevention of wildfire has led to canopy closure and woody plant incursion into open areas (Smallidge and Leopold, 1997; Swengel and Swengel, 2001). This is especially true of pine barrens ecosystems in northeastern North America. Historically, these systems were likely a mosaic of scrub oak (Quercus ilicifolia) dominated open areas interspersed with older forests of pitch pine (Pinus rigida) (Barbour et al., 1998; WHRC, 1998; Motzkin et al., 2002). Large portions of the remaining pine barrens now have closed canopy forests. Vegetation management along transmission line corridors may be one of the few disturbances still occurring frequently and on a sufficient scale in these ecosystems to at least partially mimic natural disturbances, such as wildfire.

In Massachusetts, pine barrens provide critical habitat for 26 of the 43 threatened, endangered, or special concern species of Lepidoptera on the State list (NHESP, 2003; Wagner et al., 2003). The preponderance of pine barrens species on the list can be attributed to overall losses of this habitat, and fragmentation, development, and the loss of early successional habitat in remaining areas (CPBC, 1996; New, 1997; Wag-

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

ner et al., 2003). The importance of early successional habitat for threatened Lepidoptera is due to several factors. For specialist species, early successional habitat may be critical for the propagation and persistence of host plants for their larvae (Smallidge and Leopold, 1997). The Karner blue butterfly (*Lycaeides melissa samuelis*) is a good example, its obligate larval host plant, blue lupine (*Lupinus perennis*), can not persist under a wooded overstory (Smallidge et al., 1996). Adults of other species feed on specific nectaring or require open areas as dispersal or courtship corridors (Sutcliffe and Thomas, 1996). In contrast to host plant specialists such as Karner blue, some moths are more abundant in early successional habitats even though their host plants are widespread and found in both early and late successional communities. Mechanisms driving the spatial distribution of these species may be more complex and may incorporate such factors as environmentally-driven changes in host plant quality and/or variation in natural enemy populations.

The spatial and temporal distribution of herbivorous insects is driven by a number of selective forces. While host plant quality is vital to the growth and establishment of insect herbivores (Mattson, 1980; Scriber and Slansky, 1981; Zalucki et al., 2002), the avoidance of natural enemies may be equally as crucial (Schultz, 1983; Price, 1987; Stamp, 2001; Williams et al., 2001). Life history traits timed to allow for successful development on high quality foliage while avoiding peak periods of natural enemy abundance are likely to be favored by natural selection (Schultz, 1983; Tauber et al., 1986; Lill, 2001; Williams et al., 2001). Thus, preference for one habitat over another may be predicated on both host quality *and* natural enemy abundance. By altering the spatial structure of the environment, succession may mediate or enhance the threat posed by natural enemies, either directly by changing natural enemy behavior, or indirectly through alteration in host plant quality (Langellotto and Denno, 2004).

Insect parasitoids are an important factor regulating the survival of larval Lepidoptera. These insects, primarily belonging to the orders Hymenoptera and Diptera, lay eggs or place their own larvae within or on caterpillars (Godfray, 1994). The immature parasitoids then consume their living host and ultimately kill it. While the vast majority of parasitoids are native and are a natural factor regulating insect herbivore populations, one introduced species has recently received considerable attention in both the scientific literature (Boettner et al., 2000; Kellogg et al., 2003) and popular press (New York Times, 3/6/2001) for its detrimental effects on native species. This species, *Compsilura concinnata* (Diptera: Tachinidae) was originally introduced for biological control of gypsy moth in 1906 (Howard and Fiske, 1911) but has subsequently been recorded from more than 180 species of North American Lepidoptera (Arnaud, 1978). Numerous species of our most spectacular native moths, the giant silk moths (Saturniidae), have become increasingly threatened and even extirpated in parts of the Northeast (Schweitzer, 1988), and it has been hypothesized that this fly may be at least partially responsible (Boettner et al., 2000). Ongoing research suggested that the effectiveness of this parasitoid may be compromised in simplified habitats or those characterized by a lack of uniform forest cover (D. Parry, unpublished manuscript).

The objective of our study was to determine whether the interaction between the invasive tachinid fly *C. concinnata* and three native Lepidopteran hosts might be altered in early successional habitat maintained by vegetation management along electric transmission line rights-of-way (ROW). Specifically, we were interested in whether the efficacy of the parasitoid might be reduced by the patchy, open nature of the ROW habitat relative to the structurally more homogenous forest. We used a manipulative experimental approach to test the hypothesis that parasitism by *C. concinnata* would be reduced in managed ROW habitat.

METHODS

Research was conducted in 2001–2003 on Cape Cod in Massachusetts, USA. Cape Cod extends from the southeastern portion of MA into the Atlantic Ocean encompassing approximately 107,000 ha. The study area was located within and immediately adjacent to Cape Cod National Seashore in Barnstable County and consisted of a 9 km section of electric transmission line corridor (NSTAR Electric and Gas Corporation, Boston, MA) and the adjacent closed-canopy forest on the east side of the ROW. The width of the corridor was approximately 100 m throughout the section we used for research. Surrounding forest was typical of mature forested pine barrens regions on Cape Cod (Barbour et al., 1998). It was composed of a pitch pine and black oak (*Quercus velutina*) canopy with an understory of scrub oak, small black oaks, black huckleberry (*Gaylussacia baccata*), and lowbush blueberry (*Vaccinium angustifolium*). Woody vegetation on the right-of-way was dominated by scrub oak, with smaller proportions of black oak, black cherry (*Prunus serotina*), bear berry (*Arctostaphylos uva-ursi*), and pitch pine and had been mowed at 4–5 year intervals.

To assess the effects of early successional ROW habitat and the adjoining late successional forest on parasitism by *C. concinnata*, we used three native species of Lepidoptera, barrens buck moth (*Hemileuca maia*), yellow-necked caterpillar (*Datana ministra*), and Polyphemus moth (*Antheraea polyphemus*). Barrens buck moth is listed as a species of special concern in Massachusetts and elsewhere in the northeast (Nelson, 2002). Populations of *D. ministra* appear to have undergone considerable declines in the northeastern US (Wagner et al., 2003). Polyphemus is a widespread species and its populations appear reasonably healthy, although a number of taxonomically related silk moth species have suffered considerable declines in Massachusetts (Schweitzer, 1988; Boettner et al., 2000). All three species utilize various oaks (*Quercus spp.*) as host plants. Oviposition and larval feeding by *H. maia* is nearly exclusively on scrub oak on Cape Cod. Although listed as a generalist, *D. ministra* was found primarily on scrub oak, and to a lesser extent black oak, in the study area. We used black oak for rearing *A. polyphemus* although it is capable of feeding on many different woody plants.

A set number of plots were used for each species, which was determined by their biology (solitary or gregarious) as well as the number of larvae available to us. For *D. ministra* and *H. maia* which forage and rest together as groups, we used cohorts of 50 larvae on each experimental scrub oak clump. *Hemileuca maia* and *D. ministra* larvae were released in five plots in each habitat. A different design was used for Polyphemus, the larvae of which are solitary feeders. To replicate natural densities, we utilized individual black oak saplings. We treated individual trees within a larger area as a single 'plot'. We used two densities within each area, one larva/tree or five larva/tree for a total of 20 trees with 5 larvae and 40–60 trees with a single larva each. For the purpose of this paper, we pooled all trees within a plot to assess the mean parasitism level.

We quantified parasitism of each species by deploying the appropriate number of individuals at marked locations and retrieving them from the field after set time intervals. This sequential rear, release, and recapture technique is an effective method to estimate mortality from natural enemies in Lepidoptera (Boettner et al., 2000; Kellogg et al., 2003). After collection, larvae were returned to the laboratory and then reared until adult emergence or death. Any emerged parasitoids were identified and an estimate of percent parasitism was calculated for each cohort of larvae. For *A. polyphemus*, we determined parasitism over a 7 day period that spanned part of the 4th and 5th instars. *Datana ministra* was assessed using 4th and 5th instars over a 9 day period. Parasitism of *H. maia* was quantified in more detail and over a longer time period. Rather than a single time interval as was used with the other species, we deployed and retrieved caterpillars for each of the six larval instars and quantified parasitism for each stage. We computed the cumulative proportion (p) of *H. maia* larvae killed: $p = 1 - (1 - m_1)(1 - m_2)\ldots(1 - m_3)$ where m_i is the proportion of larvae dying from *C. concinnata* between collection i and $i + 1$ or if i was the last collection, at any time after that. For each of the three species, we compared percent parasitism among the two habitat types using one-way analysis of variance (ANOVA).

RESULTS

Our results suggest that early successional landscape, characteristic of the managed ROW at the study site, altered the relationship between an invasive parasitoid and its native lepidopteran hosts. Polyphemus caterpillars had significantly higher parasitism ($F_{1,6} = 7.5$, $p < 0.04$) in forested habitat than in the open, sparsely vegetated right-of-way habitat (Fig. 1a). In forested areas, parasitism was as high as 84.9% in one plot even though the larvae were deployed in the field for only

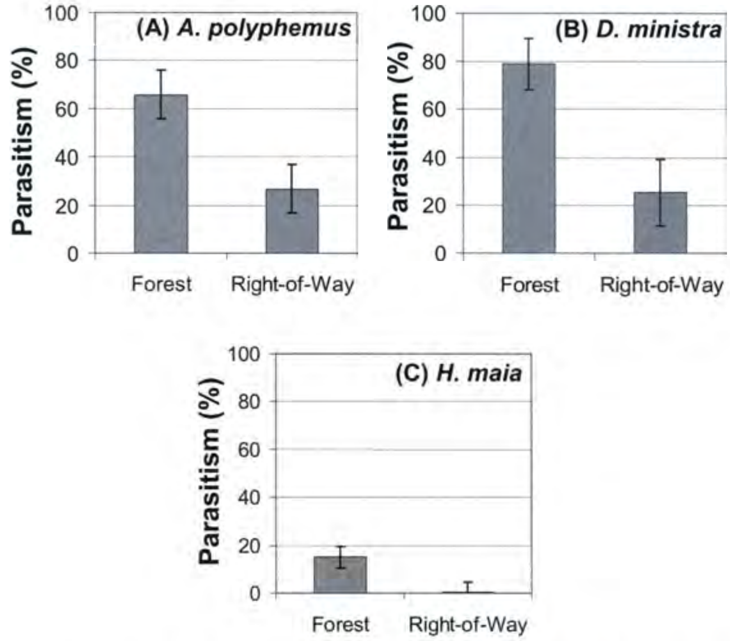

Fig. 1. Mean (± SE) percentage parasitism caused by the exotic parasitoid *C. concinnata* on (A) Polyphemus, (B) yellow-necked caterpillar, and (C) barrens buck moth, in two habitats. Cohorts of larvae were deployed in plots along a transmission line right-of-way and compared with same-sized cohorts deployed in the adjacent mature forest. Means were calculated from all plots in a habitat.

one week. For *D. ministra*, parasitism by *C. concinnata* was also significantly higher ($F_{1,6} = 9.0$, $p < 0.03$) in larvae deployed in forested areas adjacent to the power line corridor (Fig. 1b). Bird predation eliminated larvae deployed at two of the five power line plots reducing the statistical power of this comparison. Parasitism of *H. maia* by *C. concinnata* was much lower than the other two species. Nonetheless, parasitism was significantly higher ($F_{1,8} = 5.3$, $p < 0.05$) in the forested habitat (Fig. 1c). No other species of parasitoid attacked *A. polyphemus*. A native species of tachinid, (probably *Archytas metallicus*), was reared from *D. ministra* at very low levels (<1%). In addition to *C. concinnata*, three native species, *Hyposoter fugitivus, Meteorus autographae*, and *Leschenaultia fulvipes*, were reared from *H. maia* in low numbers.

DISCUSSION

The distribution of many insect herbivores is at least partially a function of the threat imposed by natural enemies, either through direct attacks or indirectly by causing herbivores to seek out niches that act as refuges from natural enemy attack (Price, 1987; Williams et al., 2001). The habitat structure created by vegetation patterns on power line ROW may offer enemy-free or at least enemy-reduced space for some Lepidoptera. Enemy-free space is defined as "ways of living that reduce or eliminate a species' vulnerability to one or more species of natural enemies" (Jeffries and Lawton, 1984). This is accomplished through spatial or temporal adjustments to life history attributes so as to minimize exposure. Our study showed that all three species had lower parasitism in the ROW habitat. Surveys suggest that *H. maia* and *D. ministra* are most abundant on small scrub oaks in relatively open areas (Schweitzer, 1983; Nelson, 2002; D. Parry, personal observation). While not demonstrating causality, our study does suggest that reduced parasitism could account for the observed spatial distribution.

Parasitism by the invasive tachinid fly *C. concinnata* has been implicated in the decline of several native silk moths and some notodontids (Boettner et al., 2000; Wagner et al., 2003). Our results strongly support the idea that *C. concinnata* can be an important or dominant source of mortality for tree-feeding macrolepidopterans. In mature, closed-canopy forest, parasitism was more than three times as high as in ROW environments for each of the three species examined. For two species, *A. polyphemus* and *D. ministra*, the dominant source of mortality was *C. concinnata*. It is unclear why *C. concinnata* is more successful in forested habitats. One possibility is that the spatial structure of the early successional habitat with clumps of open growing shrubs interspersed with open areas of grasses or other ground cover may disrupt the cues this fly uses to find hosts. Recent research on another host species, the invasive browntail moth (*Euproctis chrysorrhoea*), clearly showed that *C. concinnata* was least successful in the sparsely vegetated sand dune habitats and most successful in forested habitats on Cape Cod (J.S. Elkinton et al., unpublished manuscript).

Overall parasitism of *H. maia* was surprisingly low. Other studies have suggested that *C. concinnata* may have a larger impact on *Hemileuca* (Boettner et al., 2000; Stamp, 1990). On Cape Cod, Selfridge (2004) recorded higher rates of parasitism by *C. concinnata* in both forest and ROW habitat in 2002 than in 2003. When assessing parasitism rates, caution is warranted. A low parasitism rate does not necessarily indicate lack of importance. If mortality from other sources is high, 15% additional mortality as we showed here, may be very significant and could be the difference between persistence and elimination of a population at a site. Thus we should not dismiss the importance of *C. concinnata* in the population dynamics of *H. maia*. Furthermore, parasitism by *C. concinnata* may fluctuate temporally as well as spatially. Therefore comprehensive long term studies are required to determine how much of a role, if any, it plays in the spatial structure of *H. maia* populations.

While our study focused solely on parasitism by *C. concinnata*, other sources of mortality may be equally if not more important to these Lepidoptera and may also be affected by changes to habitat structure. Larval 'disappearance' is often high in these types of experiments and in many cases may be attributable to predation by birds. Disappearance of *A. polyphemus* was higher in the open early successional habitat (55%) than it was in the forest (35%). Similarly, larvae from two entire ROW plots of *D. ministra* disappeared. These losses may reflect different species of birds in each habitat, or more success or greater effort foraging in ROW habitat by the same species. Higher mortality by one agent may be compensated for by another agent (Campbell and Torgersen, 1983). Thus overall patterns of mortality in two habitats may be similar when all factors are quantified.

CONCLUSIONS

We show that the environment created by vegetation management along electrical transmission ROW can alter the relationship between a parasitoid and its host, adding another dimension to our understanding of the benefits conferred by early successional landscapes to Lepidoptera. However, our study captured only relatively short 'snapshots' in the lifecycle of two of the three species. Our results therefore should be interpreted cautiously, precluding definitive management recommendations. Nonetheless, they do suggest that current management practices may be inadequate for many species. Management techniques focused around an umbrella species (sensu Simberloff,

1998) may result in inadequate protection or may even run counter to the needs of other rare species in the same environment. For example, management of ROW for Karner blue or other herb-feeding butterflies in pine barrens may focus on facilitation of habitat for lupines and nectaring plants, but this could reduce critical habitat for species feeding on woody plants. These issues need to be considered when developing comprehensive management plans for Lepidoptera in pine barrens.

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REFERENCES

Arnaud, P.H., Jr. 1978. A host-parasite catalog of North American Tachinidae (Diptera). Publication 1319. U.S. Science and Education Administration, Washington, D.C.

Boettner, G.H., J.S. Elkinton, and C.J. Boettner. 2000. Effects of a biological control introduction on three nontarget native species of saturniids moths. Conservation Biology, 14: 1798–1806.

Barbour, H., T. Simmons, P. Swain, and H. Woolsey. 1998. Our Irreplaceable Heritage: Protecting Biodiversity in Massachusetts. Massachusetts Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries & Wildlife, Westborough, MA, and The Nature Conservancy, Massachusetts Chapter, Boston, MA.

Campbell, R.W. and T.R. Torgersen. 1983. Compensatory mortality in defoliator population dynamics. Environmental Entomology, 12: 630–632.

Central Pine Barrens Joint Planning and Policy Commission (CPBC). 1996. Central pine barrens comprehensive land use plan, Volume 2: Existing Conditions, Chapter 5: Ecosystems Overview. Grand River, NY.

Elkinton et al. Unknown. Redemption for a rogue biological control agent? Implicating Compsilura concinnata in the demise of the invasive browntail moth. Unpublished.

Godfray, H.C.J. 1994. Parasitoids: Behavioral and Evolutionary Ecology. Princeton University Press, Princeton, New Jersey.

Jeffries, M.J. and J.H. Lawton. 1984. Enemy-free space and the structure of ecological communities. Biological Journal of the Linnaean Society, 23: 269–286.

Howard, L.O. and W.F. Fiske. 1911. The importation into the United States of the parasites of the gipsy moth and the brown-tail moth. United States Department of Agriculture. Bulletin 91.

Kellogg, S.K., L.S. Fink, and L.P. Brower. 2003. Parasitism of native Luna moths, Actias luna (L.) (Lepidoptera: Saturniidae) by the introduced Compsilura concinnata (Meigen) (Diptera: Tachinidae) in Central Virginia, and their hyperparasitism by trigonalid wasps (Hymenoptera: Trigonalidae). Environmental Entomology, 32: 1019–1027.

Langellotto, G.A. and R.F. Denno. 2004. Responses of invertebrate natural enemies to complex-structured habitats: a meta-analytical synthesis. Oecologia, 139: 1–10.

Lill, J.T. 2001. Selection on herbivore life-history traits by the first and third trophic levels: the devil and the deep blue sea revisited. Evolution, 55: 2236–2247.

Mattson, W.J. 1980. Herbivory in relation to plant-nitrogen content. Annual Review of Ecology and Systematics, 11: 119–161.

Motzkin, G., R. Eberhardt, B. Hall, D.R. Foster, J. Harrod, and D. MacDonald. 2002. Vegetation variation across Cape Cod, Massachusetts: environmental and historical determinants. Journal of Biogeography, 29: 1439–1454.

Nelson, M.W. 2002. Element Abstract: Hemileuca maia. Massachusetts Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, Westborough, MA.

New, T.R. 1997. Butterfly Conservation. 2nd Edition. Oxford University Press. South Melbourne, Australia.

New York Times. 2001. When Biological Control Gets Out of Control. C. Kaesuk Yoon. 3/6/2001.

Natural Heritage & Endangered Species Program (NHESP). 2003. Massachusetts list of endangered, threatened and special concern species. Massachusetts Division of Fisheries and Wildlife. Westborough, MA.

Parry, D. Unknown. Personal observation.

Parry, D. Unknown. Unpublished data.

Price, P. W. 1987. The role of natural enemies in insect populations. Pages 287–312 in P. Barbosa and J.C. Schultz, eds. Insect Outbreaks. Academic Press, New York.

Selfridge, J.A. 2004. The Effects of Natural Enemies and Host Plant Quality on the Distribution of Barrens Buck Moth (Hemileuca maia, Family: Saturniidae). MS Thesis. SUNY – College of Environmental Science & Forestry, Syracuse, NY.

Schultz, J.C. 1983. Habitat selection and foraging tactics of caterpillars in heterogeneous trees. Pages 61–90 in Variable Plants and Herbivores in Natural and Managed Systems. R.F. Denno & M.S. McClure, eds. Academic Press, Inc. New York, NY.

Schweitzer, D.F. 1983. Hemileuca maia, the barrens buck moth in New England: current status. Report prepared for the Massachusetts Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, Westborough, MA.

Schweitzer, D.F. 1988. Status of Saturniidae in the northeastern USA: a quick review. News of the Lepidopterists' Society, 1: 4–5.

Scriber, J.M. and F. Slansky, Jr. 1981. The nutritional ecology of immature insects. Annual Review of Entomology, 26: 183–211.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological Conservation, 83: 247–257.

Smallidge, P.J. and D.J. Leopold. 1997. Vegetation management for the maintenance and conservation of butterfly habitats in temperate human-dominated landscapes. Landscape and Urban Planning, 38: 259–280.

Smallidge, P.J., D.J. Leopold, and C.M. Allen. 1996. Community characteristics and vegetation management of Karner blue butterfly (Lycaeides melissa samuelis) habitats on rights-of-way in East-Central New York, USA. Journal of Applied Ecology, 33: 1405–1419.

Stamp, N. 2001. Enemy-free space via host plant chemistry and dispersion: assessing the influence of tri-trophic interactions. Oecologia, 128: 153–163.

Stamp, N.E. 1990. Parasitism of New England Buck Moth caterpillars (Hemileuca lucina: Saturniidae) by tachinid flies. Journal of the Lepidopterists' Society, 44: 199–200.

Sutcliffe, O.L. and C.D. Thomas. 1996. Open corridors appear to facilitate dispersal by ringlet butterflies (*Aphantopus hyperantus*) between woodland clearings. Conservation Biology, 10: 1359–1365.

Swengel A.B. and S.R. Swengel. 2001. Effects of prairie and barrens management on butterfly faunal composition. Biodiversity and Conservation, 10: 1757–1785.

Tauber, M.J., C.A. Tauber, and S. Masaki. 1986. Seasonal adaptations of insects. Oxford University Press, New York.

Wagner, D.L., M.W. Nelson, and D.F. Schweitzer. 2003. Shrubland Lepidoptera of southern New England and southeastern New York: ecology, conservation and management. Forest Ecology and Management, 185: 95–112.

Woods Hole Research Center (WHRC). 1998. An electronic atlas of the Cape Cod environment. http://www.whrc.org/ccatlas/landcover/landcover.htm.

Williams, I.S., T.H. Jones, and S.E. Hartley. 2001. The role of resources and natural enemies in determining the distribution of an insect herbivore population. Ecological Entomology, 26: 204–211.

Zalucki, M.P., A.R. Clarke, and S.B. Malcolm. 2002. Ecology and behavior of first instar larval Lepidoptera. Annual Review of Entomology, 47: 361–393.

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Selected Non-native Plants of Rights-of-Ways (ROWs) in the Southeastern United States and Associated Impacts

Jeanne C. Jones, Dale H. Arner, John Byrd, Lisa Yager, and Sarah Gallagher

Over thirty species of non-native, herbaceous and semi-woody plants may be present on road, pipeline, and utility rights-of-way (ROWs) in the southeastern United States. The ecological and economic impacts of these species vary depending on vegetation competition and colonization trends, wildlife food and cover value, and livestock forage value. Some plants, such as annual lespedezas and clovers, are non-native species that are naturalized in southeastern habitats. These plants have value for livestock and wildlife forage, soil stabilization, and soil quality enhancement with limited negative impacts to natural communities. Because of their growth habits and value, these species are desirable for vegetative reclamation on disturbed sites of ROWs. Some species, such as sericea lespedeza and tall fescue, were originally planted for soil stabilization, but these species have limited value for most species of wildlife and can limit native plant diversity. Of greatest concern are the highly invasive introduced plants, such as cogongrass and kudzu. Originally introduced through intentional planting in some areas, these species are now established in dense colonies on thousands of hectares of ROWs. After establishment, these species limit native biological diversity, degrade wildlife habitat quality, and reduce property values. Colonization studies indicate that cogongrass spread is enhanced by management that creates bare soil and transfers vegetative propagules to new sites. Because of the life strategies of many non-native invasive species, newly constructed and maintained ROWs can serve as corridors for dispersal of these species. Early detection and integrated pest management are important in the cost-effective control of invasive perennial plants. Due to economic and ecological impacts of invasive plant species, agencies and companies managing ROWs should develop plans to monitor and eradicate these species on lands under their jurisdiction.

Keywords: Invasive plants, non-native plants, invasive species, kudzu, cogongrass, right-of-way

INTRODUCTION

Roadside and utility rights-of-way (ROWs) of the southeastern U.S. typically are dominated by early successional plant communities, comprised of shrubs and herbaceous plants. Wildlife species that require early successional habitats for corridors, nesting, and feeding can benefit from herbaceous plant communities that are characteristic of maintained ROWs. Herbaceous plants (grasses, forbs, and legumes) that generally are common to ROWs in the southeast provide foods for a diversity of wildlife species. Flowering forbs and legumes are attractive to invertebrates and non-game birds due to nectar and pollen production (Miller and Miller, 1999). Seed produced by forbs, legumes, and grasses produce desirable foods of upland game birds, such as eastern wild turkey (*Meleagris gallopavo*), northern bobwhite quail (*Colinus virginicus*), and mourning doves (*Zenaida macroura*); non-game grassland birds; and small mammals (Miller and Miller, 1999). Herbaceous plants are used as forage by rabbits (*Sylvilagus floridanus, S. palustris, S. aquaticus*), white-tailed deer (*Odocoileus virginianus*), and upland game birds. The structure created by herbaceous plant communities provides important nesting and escape cover for ground-nesting species, such as turkey, quail,

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and grassland sparrows; rabbits, and rodents. Habitat quality produced by herbaceous plant communities on ROWs is related to the diversity of plant species and vegetative structure within the community. These aspects influence the periodicity or seasonal availability of plant foods, the nutritional quality and palatability of available plant foods, and variety of cover types available for wildlife. Both native and non-native plants can provide plant foods and cover for wildlife on ROWs, and some non-native plants produce desirable wildlife food and cover. However, non-native plants that become invasive and dominate a site tend to create monotypic stands over time that limits plant diversity and degrades wildlife habitat quality.

Today, many non-native plants are established across the southeastern U.S. landscape along roadsides and on utility ROWs. Many of these plants are invasive, spreading to adjacent sites where they severely impact land productivity for agriculture, forestry, and wildlife. Many non-native, herbaceous and semi-woody plants may be present on road, pipeline, and utility line ROWs in the Lower and Middle Gulf Coastal Plain of the southeastern U.S. (Miller, 2003). The ecological and economic impacts of these species vary depending on vegetation competition and colonization trends, wildlife food and cover value, and livestock forage value. The primary objectives of our paper are to discuss characteristics and management of three genera of beneficial non-native plants and four species of invasive non-native plants. Although discussion of all non-native plants is not possible in this paper, we offer discussion of selected species that may shed light on future vegetation monitoring and management approaches that are needed to control the spread of invasive plants along ROWs in the southeastern U.S.

NON-NATIVE PLANTS OF SOUTHEASTERN ROWS

Beneficial annual plants

Selected non-native plants, such as annual lespedezas, vetches, and clovers, are valued and planted for livestock and wildlife forage, soil stabilization, and soil quality enhancement with limited negative impacts to wildlife habitat quality, reforestation, and agriculture. Annual legumes are often seeded in companion plantings with grasses for erosion control on roadsides, utility line ROWs, disposal areas of public works projects, reclaimed surface mines, and rehabilitated military training sites. In general, these species exhibit annual or biennial growth cycles and limited invasive tendencies. Without replanting and maintenance, coverage of these species generally declines over time, exhibiting limited spreading into adjacent habitats. Due to the lack of well-established root systems typical of perennial plants, these annual plants can generally be controlled, if necessary, through cost effective integrative approaches that include soil disturbance, grazing, frequent mowing, or selective herbicide application. Included in this group are the cool season and warm season annual legumes, as clovers (*Trifolium* spp.), vetches (*Vicia* spp.), and lespedezas (*Kummerowia striata, K. stipulacea*). These legumes can enhance soil quality through nitrogen fixation in the root zones, provide coverage for soil stabilization, attract invertebrates, such as butterflies, and produce foraging sites for game and non-game wildlife, including white-tailed deer, rabbits, eastern wild turkey, northern bobwhites, and eastern bluebirds (*Sialia sialis*). Because of their wildlife food value, these non-native legumes have been planted into terrestrial habitats of the southeast to benefit upland game species. Many studies have recorded the food value of Kobe lespedeza for upland game wildlife, such as rabbits and quail (Jones et al., 1994; Yarrow and Yarrow, 1999; Dickson, 2001). Vetch and clovers also rank high in terms of use by native wildlife species (Yarrow and Yarrow, 1999). In Mississippi, Brazil (1993) found that vetch seed was in the top ten food items taken by more than 2000 bobwhite quail harvested over a three-year period. Because vetches and clovers are cool season annuals, growing from fall through early spring, they also provide green succulent vegetation for rabbits, turkey, and deer when forage is scarce.

Invasive perennial plants

In contrast to the aforementioned annual legumes, over 33 species of non-native plants currently are established in 13 states of the southeastern United States (Miller, 2003). Most of these species were introduced for ornamental use, erosion control, livestock forage, or wildlife food plantings. Invasions of these non-natives into habitats of the southeast are largely unmonitored and increasing where they degrade native diversity and wildlife habitat, reduce forest productivity, and hinder land use alternatives (Miller, 2003). Many of these species are favored by exposure of bare soils, site disturbance, and early successional habitat stages. Furthermore, seed and vegetative propagules of these species are easily transported on soil-moving and mowing equipment, such as clippers, mowers, and bulldozers. Because of these factors, these species are common to and dispersed along utility and roadside ROWs through maintenance and construction activities. They have become established in and along ROWs routes throughout the southeast. Due to their invasive nature, these plants typically spread from ROWs into adjacent forestlands, croplands, and wildlife habitats where they degrade land productivity and value, aesthetic quality, and native faunal and floral diversity (Miller, 2003).

Due to their economic and ecological impacts, monitoring and control programs have been initiated in many states. Also, many southern states have adopted statewide regulations to control the sales, transport, and spread of invasive plants. Selected invasive plant species, such as cogongrass (*Cylindrica imperata*), are listed as noxious weeds by the Federal Noxious Weed Act. Consequently, federal agencies, such as the Department of Defense, U.S.D.A. Forest Service, and U.S.D.I. Fish and Wildlife Service, must monitor and control noxious weed species within their management inholdings. Because ROWs transect public land bases, ROW managers should work cooperatively with public land managers to address and implement invasive plant control programs. Additionally, dispersal of invasive plants on ROWs that transect private lands can create liability issues related to the negative impacts of invasive species on private property value and uses. Because of invasive species infestation trends, ROW managers and planners should consider cumulative impacts of these species to adjacent private and public properties. Ultimately, successful and cost-effective control of invasive plant species on private and public lands must include control of source populations and eradication of these populations along dispersal corridors, such as roadsides and utility ROWs.

Selected non-native species were introduced specifically for livestock forage or soil stabilization. Introduced because of their hardiness and tendency to dominate ground cover, these species now limit native biological diversity, aesthetics, and reforestation successes across the southeastern U.S.

Tall Fescue (Lolium arundinaceum; formerly Festuca elatior, F. arundinacea)

Tall fescue is a perennial grass that was introduced from Europe in the mid-1800's. In the mid 1930's, fescue became recognized as a valuable forage for livestock when the ecotype Kentucky 31 was discovered (Miller, 2003). This cool season bunch grass reaches from 60 to 120 cm in height and forms tufted clumps that yield flowers in early spring. Seeds are produced from early summer through November when above ground growth goes into semi-dormancy. Now widely distributed throughout the U.S., tall fescue has been planted extensively for livestock forage, turf, soil stabilization, and wildlife food plots. Tall fescue grows as a cool season bunch grass in forest openings and edges. Large, monotypic stands may occur on road and utility ROWs, reclaimed mine sites and public works projects, levees and berms of water bodies and waterways, and fallow agricultural lands. Fescue spreads mostly by expanding root crowns and less by seed into new forest plantations, fallow fields, and along ROWs and roads.

Due to heaviest growth during the winter and spring months, tall fescue gained popularity as a food plot species for white-tailed deer in the southeast. However, tall fescue has limited value for wildlife. Most tall fescue is infected with an endophytic fungus that causes reproductive and physiological problems in wildlife and livestock. Specifically, endophytic-infected fescue has been reported to cause fatal intestinal lesions and reproductive failures in rabbits that ingested vegetative parts of the plant and mortality in quail that were fed the seed (Yarrow and Yarrow, 1999; Dickson, 2001). In addition to limited forage value, tall fescue also displaces valuable wildlife food plants through dense sod formation and allelopathy.

Kudzu (Pueraria montana)

This leguminous vine was introduced from China into the U.S. from 1920–1950 for erosion control and livestock forage. Over 2 million acres were planted to kudzu during this time period and in the following decades, kudzu spread beyond planted areas and now occurs throughout the southeastern United States, as far north as Connecticut, and west to Illinois, Nebraska, and Oklahoma (Miller and Miller, 1999). The plants exhibit twining or trailing semi-woody, many noded stems that may reach over 33 m in length. Roots are tuberous and may reach depths ranging from 1 to 6 m beneath the soil's surface. Roots may arise along stem from each node that contacts soil. Spread of kudzu can arise from rooting along stem nodes when vines contact ground or are covered by leaf litter and by viable seed. Root and stem propagules and seed can be spread on ROWs by mowing and soil moving equipment. High growth rates of over 0.3 m per day produces dense mats of vegetation that generally exclude other plants with the exception of some evergreen trees and shrubs and blackberries (*Rubus* spp.; Miller, 2003). Monitoring and control of kudzu is conducted on many public lands to limit negative impacts to timber resources, native plant diversity, and wildlife habitat. Despite eradication programs, kudzu is still common along road and utility line rights-of-way and stream banks where it out competes native herbaceous and woody plants. Although kudzu is a pest species, the plant is readily eaten by white-tailed deer and dense kudzu thickets provide excellent cover for young deer fawns. Subsequently, kudzu has been marketed in the southeastern by commercial seed sources for deer food plot plantings in recent years, despite it's invasive nature and impacts on land values.

Sericeal lespedeza (Lespedeza cuneata)

Introduced in the eastern U.S. in 1899 from Japan, sericea lespedeza is an upright to ascending perennial legume that develops dense stem densities that arise from woody root crowns. Reaching up to 1.5 m in height, leafy branching stems produce many white flowers from July–September that yield seeds through winter months. Although germination rates of seed are reported to be low, plants produce many seeds that remain viable for many decades. Thus, spread of sericea lespedeza occurs through spreading of seed from infestation sites or plantings (Miller, 2003).

The spread of sericea lespedeza has been accelerated by government programs that promoted plantings for erosion control. Reclamation plantings including this plant have been common on reclaimed mine sites, disposal areas of public works projects, and road and utility ROWs. On reclaimed lands in Mississippi where sericea lespedeza was included in reclamation plantings, dense stands excluded native plant colonization, reduced survival of wildlife shrub plantings, and limited the occurrence of wildlife food plants (Jones et al., 1994). Long-term monitoring of vegetative succession on 20 disposal areas of the Tennessee–Tombigbee Waterway (TTW) in Mississippi revealed that percent coverage of sericea lespedeza increased from a mean coverage of 20% in 1982 to over 70% in 1992. This trend was due to increases in coverage on disposal areas where it had been planted and to invasions of the plant into new areas over time. Conversely, native plant coverage and species richness declined (<15% coverage, <5 species, respectively) on sites infested with >70% coverage of sericea lespedeza. Native plant diversity and coverage were inversely related to sericea coverage on 35 reclaimed disposal areas of the TTW over the ten-year period ($P < 0.001$; $r > 0.80$). In dense coverages (>70%) of sericea lespedeza less than three quail food plant species were generally found (Jones et al., 1994).

Unlike native and annual lespedezas, sericea lespedeza produces seed high in tannic acid that are taken marginally by quail. Jones et al. (1994) reported use of sericea seed by <40% of the harvested quail on disposal areas of the TTW despite high availability and ground coverage (>70%) of this plant. Most use of sericea seed was recorded during late February when most other seed were limited (Jones et al., 1994). In contrast, >60% of the quail harvested in the four-year study consumed seed of native and kobe lespedezas (Lespedeza virginica, L. striata) despite low availability and <2.5% coverage on the study area (Jones et al., 1994). Therefore, they concluded that native and kobe lespedeza were more highly preferred quail food plants than sericea lespedeza and that native and annual lespedezas should be used in reclamation plantings and managed in early successional habitats, such disposal areas, mine sites, and ROWs.

Currently, 13 southeastern states have infestations along roadsides, on ROWs, and reclaimed lands, such as mine sites and public works sites. The plant commonly occurs in forest openings and forest roads, dry upland woodlands with open canopy conditions, old fields, fallow areas of agricultural lands, and in urban areas (Miller, 2003). After establishment and several growing seasons, sericea forms dense stands that sprout from well-established root crowns yielding stem densities of >150 stems/m and ground coverages exceeding 90% (Jones et al., 1996). Infestation and dominance of this plant prevents forest regeneration, limits native plant diversity, and degrades wildlife habitat quality (Jones et al., 1994; Jones et al., 1996; Miller, 2003).

Cogongrass (Imperata cylindrica)

Listed on the Federal Noxious Weed Act as an invasive pest species, cogongrass is a perennial that grows to heights of 1 to 1.5 m and forms dense monotypic stands of above ground leaves of 2.5 cm in width. Finely toothed leaf blades exhibit a prominent midrib, are pubescent on the upper side, and embedded with silica crystals. The plant flowers in early spring producing abundant panicle-like spikes that yield whitish plumes of aerially dispersed seeds (Johnson and Shilling, 1998).

Cogongrass was first introduced accidentally as shipping material into the United States in 1911 at Mobile, Alabama. It was later intentionally introduced as a potential forage crop and solution to soil erosion (King and Grace, 2000; Johnson and Shilling, 1998). Since its introduction this invasive species has become established throughout the southeastern U.S. in forests, rangelands, pastures, roadsides, reclaimed mining areas, and natural areas (King and Grace, 2000).

Cogongrass poses an immense ecological concern in the United States and is listed in the top 7 most invasive weeds globally. It can successfully out compete native plants in many habitat types, especially in areas with disturbance and bare soil exposure (Johnson and Shilling, 1998). Lippincott (1997) found that cogongrass displaced natural vegetation, reduces recruitment of planted seeds and seedlings, alters soil processes, and produces higher and hotter fires than native grasses in the Florida pine sandhills (Johnson and Shilling, 1998). In addition, the forage quality is lower in cogongrass than native and agronomic plants for wildlife and livestock (Coile and Shilling, 1993; Lippincott, 1997). Due to low forage quality, loss of host plants, and cover, cogongrass displaces native insects, mammals, and birds (Johnson and Shilling, 1998).

Cogongrass reproduces vegetatively and by seed. Vegetative reproduction is supported by resilient and substantial rhizomes that can remain dormant for long periods of time before sprouting (Johnson and Shilling, 1998). Vegetative spread rate by tillers has been documented at 2.6 m/yr in established cogongrass patches in Florida sandhills (Lippincott, 1997) and 0.25 and 1.01 m/yr in road ROWs in Alabama (Dickens, 1973). Spread rates are most likely influenced by patch characteristics (size, age) and environmental conditions (light levels, soil fertility, native species composition, and type of disturbance) (D'Antonio, 1993; Higgins et al., 2000). Researchers report that shade can reduce the growth of shoots and rhizomes of cogongrass (Macdicken et al., 1997); whereas, burning can increase the rate of tiller spread in the Florida sandhill (Lippincott, 1997). Cogongrass is propagated primarily through rhizomes moved by land management activities, such as disking and mowing (Johnson and Shilling, 1998). Soil disturbance, such as tilling, promoted cogongrass seedling growth in wet pine savannahs of coastal Mississippi (King, 1999; King and

Grace, 2000). Individual cogongrass plants produce thousands of seeds that are wind dispersed (Johnson and Shilling, 1998) and these wind-dispersed seeds may travel over 100 m in open fields. Seed viability may vary depending on area; however, high seed production ensures adequate seed germination potential. Highest germination and establishment rates occur where seed comes into contact with bare surface soil.

Early detection and a proactive integrated management approach are essential aspects in the long-term control and eradication of cogongrass. Selected researchers report that eradicating smaller, outlying patches of the invasive species rather than the larger patches is more efficient at controlling cogongrass. Conversely, other researchers have reported that eradicating the larger source patches of invasive species is a more effective control (Johnson and Schilling, 1998). Johnson and Shilling (1998) recommend an integrated mechanical-herbicide treatment that included spring mowing, disking new growth on sites of low sensitivity and erodibility, and application of the appropriate herbicide when grass resprouts following disking. Ideally, the herbicide should be applied in early fall before the first frost. A 2% mixture of glyphosate is appropriate if immediate revegetation is planned. If revegetation is not planned; however, a 1–1.5% mixture of imazapyr is suitable. Imazapyr should not be used if there is risk of non-target plant species damage or if ground water contamination is possible (Johnson and Shilling, 1998). Treated sites should be monitored following treatment and reoccurring grass should be treated with herbicide as necessary (Johnson and Shilling, 1998). Revegetation is highly recommended for long-term cogongrass control and erosion prevention (Johnson and Shilling, 1998).

Control of invasive plants

The most effective programs for invasive plants require an integrated pest management approach. Early detection and a combination of control measures, followed by monitoring to detect re-establishment and spread, and timely re-treatments to control re-establishment is recommended. Miller (2003) recommends the use of herbicides combined with mechanical treatment and burning, when feasible. For species, such as agronomic grasses and Kudzu, grazing can be used to reduce ground cover before and following herbicide treatment. Additionally, root raking, mowing, and prescribed fire can be used in combination with herbicide applications. Although, mechanical and fire treatment alone does not generally eradicate invasive plants, these measures can give added kill of herbicide-weakened plants or make plants more susceptible to herbicides (Miller, 2003). Miller (2003) warns; however, that mechanical disturbance, such as disking and raking, can intensify and spread invasives by chopping runners and roots into segments that resprout and by transporting seed and vegetative propagules on equipment. Therefore, mechanical measures must be accompanied by herbicide application and cleaning of disking, mowing, and raking equipment before moving to new areas.

Because invasive plants are difficult to control, managers should always select the most effective herbicide for the targeted plant species. Generally, herbicides that have soil and foliar activity are most effective with the least number of applications. However, herbicides with soil activity can damage root crowns of desirable plants in treatment sites. Also, these chemicals can be moved down slope to adjacent sites by surface run off following heavy rains. Therefore, use of these chemical near sensitive and rare plant communities should be limited. Foliar and foliar-soil active herbicides and may be applied selectively on small infestations or broadcast on large scale infestations. Active ingredients of foliar active herbicides include glyphosate, triclopyr, fosamine; whereas, imazapyr, metsulfuron and picloram are active ingredients of foliar and soil active herbicides that may be used on species discussed herein.

Most species require multiple treatments for eradication. (For specific treatment prescriptions, see Miller, 2003.) For example, cogongrass may be best controlled by use of two herbicide application per growing season, glyphosate in summer months and imazapyr in fall months. Effective eradication programs for invasive plant infestations usually requires several years of treatment and additional years of monitoring to check for re-infestation and new invasions (Miller, 2003).

Rehabilitation of treated areas

Rehabilitation is the most important phase of an invasive species eradication program. Re-establishment of desirable vegetation can impede the re-colonization of invasive plants, control erosion, and produce wildlife habitat on treated sites. If sites are not drastically disturbed and seed banks remain in place, native plants may colonize naturally. Light seeded pioneer plants generally colonize new sites within a growing season in the southeastern U.S.; heavier seeded plants may be introduced to treated sites by animals over several growing seasons. Native plant colonization may be slow on sites of low fertility that have been treated with soil active herbicides. These areas may produce limited wildlife food plants following invasive plant control. Plants that typically colonize ROWs after herbicide maintenance are broom sedge (*Andropogon spp.*), three awn grass (*Aristida spp.*), goldenrod (*Solidago spp.*), Johnsongrass (*Sorghum halapense*), tall fescue, and sericea lespedeza, the last three of which are non-native plants of limited wildlife value. Thus, establishment of native plants or annual legumes discussed earlier in this paper is prudent. Annual vetches, clovers, and lespedezas generally are available from seed companies; however, managers should make choices for annual species that are of value to wildlife and will not become pest species. Some species, such as hairy vetch (*Vicia villosa*) have exhibited inhibition of non-native and native plants and may exhibit effectiveness is slowing invasive plant recolonization.

Avoidance of perennial non-native species for rehabilitation is advised unless managers are trying to halt the recolonization of highly invasive species, such as cogongrass. In this case, use of competitive perennials that have value for wildlife and livestock forage and erosion control may be warranted. Shilling et al. (1997) found that Bahiagrass (*Paspalum notatum*) sod with greater than 75% cover prevented cogongrass from re-establishing. Lippincott (1997) found that wax myrtle (*Myrica cerifera*) survived well in cogongrass patches in the Florida sandhills. In 1999, mixtures of non-native and native plant species were used for revegetation in cogongrass control sites in Florida with limited success during drought years (Johnson, 1999). Enhancement of natural revegetation through soil amendments and other management may also have utility in slowing cogongrass re-infestation (Johnson and Shilling, 1998).

When feasible, use and enhancement of native plants for reclamation is recommended. However, cost, availability of seed and propagule sources, and under-developed methods of establishment often hinder use of native plants in reclamation plantings. In recent years, seed and vegetative propagules of native species have become increasingly available from commercial sources and tree nurseries of forestry agencies. Native legumes, such as partridge pea (*Chamaecrista fasciculata*), are readily available from commercial seed companies and are excellent food plants for gamebirds, nongame wildlife, and insects. Companion plantings of partridge pea and warm season grasses, such as indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and big and little bluestem (*Andropogon gerardii, Schizachyrum scoparium*) can create ground cover that slow invasive plant reestablishment while providing food and cover for wildlife (Yarrow and Yarrow, 1999). To receive maximum benefits of reclamation programs, species should be seeded at appropriate times and rates, and receive follow-up maintenance to keep coverage at optimal levels for limiting reinvasion by non-native plants. For example, warm season native grasses should be planted during spring to early summer and receive soil amendments according to soil test recommendations. Legumes, such as partridge pea, should be planted during February to March following inoculation with nitrogen-fixing bacteria. Scarification of partridge pea seed is recommended for optimal germination rates. Soil amendments should be applied according to soil tests and should include low nitrogen levels to benefit legumes specifically. Other maintenance activities may include use of prescribed fire to enhance native legume and grass coverage and protection of plantings from herbicide applications, and use of herbicide with low toxicity to seeded reclamation plants.

MANAGEMENT IMPLICATIONS

Research conducted on invasive perennial plants indicates that infestations and rate of spread are enhanced by management that creates bare soil and transfers vegetative propagules and seed to new sites. Consequently, ROWs can serve as corridors for dispersal of invasive plant species. Equipment and implements used in ROW of maintenance should be checked and cleaned regularly to slow this type of transport. Additionally, early detection of infestations, appropriate integrated pest management, and follow-up monitoring and reclamation are important in cost-effective control of invasive plants in the southeastern U.S. Because ROWs transect both public and private lands, occurrence of invasive plants on ROW produce source populations from which new infestations develop. Consequently, unimpeded spread and lack of control programs for invasive plant species may violate federal and state statutes and reduce land productivity for livestock, wildlife, and forestry. Due to economic and ecological impacts of invasive plant species that occur on ROWs, agencies and companies managing ROWs should develop plans to monitor and eradicate invasive plants on lands under their jurisdiction.

REFERENCES

Brazil, D.C. 1993. Winter diet of hunter-harvested northern bobwhites in Mississippi. M.S. Thesis, Dep. Wildl. and Fish. Miss. State Univ. 153 pp.

Coile, N.C. and D.G. Shilling. 1993. Cogongrass, *Imperata cylindrica*, (L.) Beauv.: a good grass gone bad! Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Botany Circular 28.

D'Antonio, C.M. 1993. Mechanisms controlling invasion of coastal plant communities by the alien succulent *Carpobrotus edulis*. Ecology, 74: 83–95.

Dickens, R. 1973. Control of cogongrass (*Imperata cylindrica*) on highway rights-of-way. State of Alabama Highway Department, Montgomery, AL. HPR Report No. 69, Research Project 930-056.

Dickson, J.G. 2001. Wildlife of Southern forests: habitat and management. Hancock House Publishers, Blaine, WA. 480 pp.

Johnson, E.R.R.L. 1999. Management of the non-native, invasive weed cogongrass (*Imperata cylindrica* (L.) Beauv.): utilizing an integrated management program. M.S. Thesis. University of Florida, Gainesville, FL.

Johnson, E.R.R.L. and D.G. Shilling. 1998. Hernando County Final Report. Agronomy Department, University of Florida, Gainesville, Florida.

Jones, J.C., D.H. Arner, and C.H. Bucciantini. 1994. Primary foods of Northern Bobwhites inhabiting disposal areas of the Tennessee–Tombigbee Waterway. Proceedings of Annual Conference of Southeastern Association of Fish and Wildlife Agencies, 48: 240–246.

Jones, J.C., D.H. Arner, and C.H. Bucciantini. 1996. Soil sampling for detection of acid overburden on small game management areas located on severely-disturbed land bases. Proceedings of Annual Conference of Southeastern Association of Fish and Wildlife Agencies, 50: 583–591.

Higgins, S.I., D.M. Richardson, and R.M. Cowling. 2000. Using a dynamic landscape model for planning management of alien plant invasions. Ecological Applications, 10: 1833–1848.

King, S.E. 1999. Factors influencing the invasion of cogongrass (*Imperata cylindrica* (L) Beauv.) in wet pine savanna communities. M.S. Thesis. University of Louisiana, Lafayette, LA.

King, S.E. and J.B. Grace. 2000. The effects of gap size and disturbance type on invasion of wet pine savanna by cogongrass, *Imperata cylindrica* (Poaceae). American Journal of Botany, 87: 1279–1286.

Lippincott, C.L. 1997. Ecological consequences of *Imperata cylindrica* (cogongrass) invasion in Florida sandhill. PhD Dissertation, University of Florida, Gainesville, FL.

Macdicken, K.G., K. Hairiah, A. Otsamo, B. Duguma, and N.M. Majid. 1997. Shade-based control of *Imperata cylindrica*: tree fallows and cover crops. Agroforestry Systems, 36: 131–149.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. American wildlife and plants: A guide to wildlife food habits. McGraw Hill Book Company, Inc. New York, NY. 187 pp.

Miller, J.H. 2003. Nonnative invasive plants of southern forests. A field guide for identification and control. USDA Forest Service, Southern Research Station. Technical Report SRS-62: 93 pp.

Miller, J.H. and K.V. Miller. 1999. Forest plants of the Southeast and their wildlife uses. Southern Weed Science Society. Craftmaster Printers, Inc., Auburn, AL.

Shilling, D.G., T.A. Bewick, J.F. Gaffney, S.K. McDonald, C.A. Chase, and E.R.R.L. Johnson. 1997. Ecology, physiology, and management of cogongrass (*Imperata cylindrica*) Final Report. Florida Institute of Phosphate. FIPR Project Number 93-03-107.

Yarrow, G.K. and D.T. Yarrow. 1999. Managing Wildlife. Alabama Wildlife Federation Sweetwater Press, Montgomery AL.

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Critical Habitat Assessment Using HEP Modeling in ROW Corridors

Allan M. Hale

An environmental and regulatory component of transmission line right-of-way (ROW) development and expansion is the determination of the presence or absence of Threatened and Endangered (T&E) species within or adjacent to the corridor. Conventional methodologies tend to be qualitative, focusing on generalized habitat components to conduct studies within the corridor requiring significant investments of time and resources. The use of the Habitat Evaluation Procedure (HEP) developed originally by the U.S. Fish and Wildlife Service for determination of Habitat Suitability Indices (HSI) was adapted and used to determine the locations of critical habitat used by several threatened and endangered wildlife species. This method uses quantitative field measurements based on the behavior and life requisites of the individual T&E species to determine the suitability of right-of-way habitats for the species under evaluation. In addition, the method permits "screening out" of habitat areas and types that do not provide the life requisite components required by the species under evaluation. In this way, habitats that contain some or all of the species' requirements are separated from habitats that do not possess the important requirements of evaluation species. This method has been employed for both wildlife and plant species on a number of right-of-way projects and provides a quantifiable basis for evaluation of siting and routing studies in addition to providing sensitive species management options for corridor expansion programs. The application of this program approach to a T&E plant species is described.

Keywords: threatened and endangered species, habitat evaluation procedure, habitat suitability indices, habitat modeling, right-of-way

INTRODUCTION

Increasingly, a key component of development of, or expansion within a transmission line right-of-way (ROW) is keyed into a determination of the presence or absence of local, state or federal Threatened and Endangered (T&E) species within or adjacent to/proximate to the corridor.

The current conventional methodologies used to make these determinations tend to be qualitative, including generalized range distribution maps focused on species habitat components. From these maps, general boundaries are developed within which to conduct walking or sampling studies within the corridor that require significant investments of time and resources.

As a means of more quantitatively determining species likelihood, the use of the Habitat Evaluation Procedure (HEP), developed originally by the U.S. Fish and Wildlife Service (U.S. FWS, 1981; 1985; Hays, 1985; 1987a; 1987b; O'Neil et al., 1988; Schamberger et al., 1986; Thomasma et al., 1991; Wakeley, 1988) for determination of Habitat Suitability Indices, was investigated. The federally threatened Running Buffalo Clover, (*Trifolium stoloniferum*) was selected and investigated as a candidate evaluation species after conducting literature review and evaluations (Bartigis, 1985; 1989; Becus, 1989; Brooks, 1983; Campbell et al., 1988; Cusick, 1988; 1989; Davis, 1987).

As part of the experiment, a computer "model" was developed for Running Buffalo Clover and was adapted and used to determine the locations of critical habitat used by the candidate T&E species. Subsequent field studies were conducted for this species,

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the results of which indicated that the methodology appeared suitable for at least this plant species and might have more widespread applications to other T&E wildlife species. The following sections describe the methods used and the field results obtained using the HEP methodology for application to ROW corridors.

MATERIALS AND METHODS

Procedure description

The HEP is a species-specific approach to habitat assessment. Through the use of computer modeling, the HEP process rates the overall value of a habitat area in direct relation to the requirements of a selected evaluation species. In general, the ratings are made on a scale from 0.0 to 1.0. Habitat quality is determined through the measurement of key variables that affect the ability of a habitat to support a given species. The overall habitat quality of an individual vegetation cover type is represented by the Habitat Suitability Index (HSI), which under normal circumstances is multiplied by the acres of "like" habitat potentially used by the evaluation species to yield Habitat Units (HUs). The HUs are the culmination of the evaluation process and are a measure of both the quality and the quantity of the evaluation species habitat found to occur in a given study area.

In normal applications, the HEP process begins by selecting a candidate species from a library array of endemic wildlife or plant species that provide an indication of the habitat "value" afforded by various dominant cover types for the specific organisms included in the model (Hays, 1987a). The present study program took a different vantage point, in that the habitats of the ROW were known and the value of the various cover types to the T&E species were determined by modeling the documented requirements of the T&E species. Mutually inclusive field variables for the sensitive species allowed the dominant cover types to be rated in terms of their ability to support the T&E species. For the first iterations, a plant, the Running Buffalo Clover (non-mobile species), was used to reduce the level of model complexity and to provide for a level of "beta" testing to determine model sensitivity and the potential of this method to applications using other species.

Evaluation species

Under normal conditions within the HEP process, several evaluation species are selected from the library of computer models and are used to characterize the individual "guilds" of species that have similar habitat resource requirements. Environmental effects on the evaluation species from the various site alternatives thus can reasonably be anticipated to occur in the other species that are part of that guild. The difference in the present approach is that the specific field variables for an individual T&E species were input into a model exclusively for that species. The Habitat Suitability Index was determined from the field screening, which was used to determine the areas that were more likely to have all of the requirements of the T&E species present.

Model development

Developing a model for an individual species required defining both the habitat variables that were important in determining the value of a habitat to the species and the specific relationship between the individual variables. The HSI model that was developed included a description of the methods of variable measurement and the method by which the field measurements to be obtained were calculated to derive the HSI value for the species within a specific habitat type. Available published and unpublished information and personal contacts with species experts provided the information sources used in the development of the model.

As an element of the model construction, a known site for the particular T&E species was actively sought through contacts with individual species experts in order to have a regionalized model source area to use for determining optimal conditions and which was used to calibrate the sensitivity of the developed model.

Model refinement

The HSI Model developed for this program combined the known habitat variables that represent life requisites for the T&E species concerned and some consideration of the relationship of individual variables affecting the species presence. The HSI model that was constructed indicated the individual field variables to be observed or measured and a method by which the measurements could be collected. Assumptions such as habitat specific affinities were included for the HSI model developed.

Prior to the field sampling program, the HSI model variables were selected and a list of the required environmental measurement variables was assembled. The habitat measurements for this program were made during the spring period because, for the species of concern, that is the time during which the species was most conspicuous (based on literature documented phonologic studies), being in its flowering phase of development. The known location of the T&E species was sampled and a portion of several existing transmission line ROWs was sampled covering various cover types, including adjacent habitats if found to differ in major composition from that found within the ROW proper.

Habitat measurement variables

The specific habitat measurement variables obtained for the model used in this program are listed and described in Table 1, which is a habitat suitability index summary (by field measurement variable) for Running Buffalo Clover.

Table 1. Running Buffalo Clover habitat suitability index summary by field measurement variable

	Field measurement variables												
Plot Number	V1	V2a	V2b	V2c	V3a	V3b	V3c	V4	V5	V6	V7	V8	Overall HSI
Plot #1**	0.90	0.75	0.35	0.20	0.60	0.40	1.00	1.00	0.85	0.75	0.85	0.90	0.794
Plot #2	0.10	0.25	0.25	0.20	0.00	0.00	0.10	0.45	0.25	0.30	0.15	0.20	0.215
Plot #3	0.20	0.30	0.20	0.20	0.30	0.20	0.10	0.10	0.20	0.45	0.15	0.10	0.204
Plot #4	0.10	0.35	0.25	0.20	0.10	0.20	0.10	0.15	0.25	0.35	0.25	0.10	0.200
Plot #5	0.35	0.30	0.20	0.20	0.10	0.40	0.25	1.00	0.25	0.30	0.25	0.65	0.410
Plot #6	0.30	0.30	0.25	0.20	0.50	0.20	0.10	1.00	0.25	0.30	0.45	0.35	0.396
Plot #7	0.30	0.40	0.35	0.20	0.00	0.00	0.40	0.45	0.40	0.25	0.25	0.65	0.344
Plot #8**	0.90	0.75	0.40	0.20	0.50	0.20	0.75	0.95	0.85	0.75	0.80	0.90	0.760
Plot #9	0.20	0.30	0.25	0.20	0.00	0.00	0.10	0.45	0.25	0.25	0.35	0.65	0.304
Plot #10	0.10	0.25	0.20	0.20	0.00	0.00	0.10	0.45	0.45	0.55	0.10	0.10	0.250

$$\text{Overall HSI} = \frac{V1 + (V2a + V2b + V2c)/3 + (V3a + V3b + V3c)/3 + V4 + V5 + V6 + V7 + V8}{8}$$

Field Measurement Variable
V1 = Percent overstory shade
V2a = Class I trees (species listed)
V2b = Class II trees (species listed)
V2c = Class III trees (species listed)
V3a = Past disturbance
V3b = Disturbance type
V3c = Disturbance duration
V4 = Soil pH
V5 = Soil type
V6 = Soil drainage class
V7 = Landscape position
V8 = Moisture regime

Plot Identification
Plot #1 = Primary Running Buffalo Clover sSite, Boone County, Kentucky
Plot #2 = Transmission Line R-O-W Site, Clermont County, Ohio
Plot #3 = Second Transmission Line R-O-W Site, Clermont County, Ohio
Plot #4 = Gas Pipeline R-O-W Site, Hamilton County, Ohio
Plot #5 = Undeveloped Mid-slope Wooded Site, Dearborn County, Indiana
Plot #6 = Undeveloped Mid-slope Wooded Site, Switzerland County, Indiana
Plot #7 = Wooded, Second Growth Site, Brown County, Ohio
Plot #8 = Shawnee Lookout Park, Hamilton County, Ohio
Plot #9 = Existing Transmission Line, Franklin County, Ohio
Plot #10 = Upland Wooded Site, Dearborn County, Indiana

** Site of known Running Buffalo presence.

Various site specific observations were made using standard field measurement approaches (Avery, 1975; Hale, 1980; 1994) at ten individual survey plots over a three-state area. The field data were reduced and from these data the individual inputs to the species model were compiled. Calculations of the HSI scores for individual habitat areas for the evaluation species were computed following the completion of the field program. Values for each of the species field variables were calculated and used to develop a range of values for each of the major vegetation cover types sampled. This resulted in a cover type specific HSI value for the specific T&E species that can be used to predict the likelihood of occurrence of the species in various cover types sampled. In this way, the major vegetation cover types were "pre-screened" for the T&E species as a precursor to additional studies. The use of a known T&E occurrence site was also incorporated into the program to assess the sensitivity of this method for indicating areas suitable to T&E species presence. In addition, this approach was used to make sampling more efficient and systematic, rather than the random sampling programs where this modeling is not conducted as part of the preliminary evaluation process.

Individual Habitat Variables incorporated into the Running Buffalo Clover model developed for this study are described in the following section.

Percent of overstory shade

The Running Buffalo Clover known occurrences seem to be almost exclusively in areas possessing partial shade (Becus, 1989; Cusick, 1989) with shading values around 40 to 50% canopy cover being optimal for this T&E species. Values of lower shading and higher shading percentages of canopy cover seem to diminish the potential for the occurrence of this species. A figure illustrating the Overstory shading relationship based on literature values and on field observations is provided as Fig. 1.

Tree species composition and density

The tree species present and the density of occurrence of those species appears to have a relationship in determining the likelihood of occurrence of the Running Buffalo. The species found most commonly associated with the presence of the Running Buffalo Clover include Black Walnut (*Juglans nigra*), Black cherry (*Prunus serotina*), Black Locust (*Robinia pseudoacacia*), and American elm (*Ulmus Americana*) (Becus, 1989; Cusick, 1989). When these species are present in density of 20 trees per hectare or about 8 individuals per acre is optimal for the T&E species, based on available quantitative literature information. A figure illustrating the tree species composition and density relationship based on literature values and on field obser-

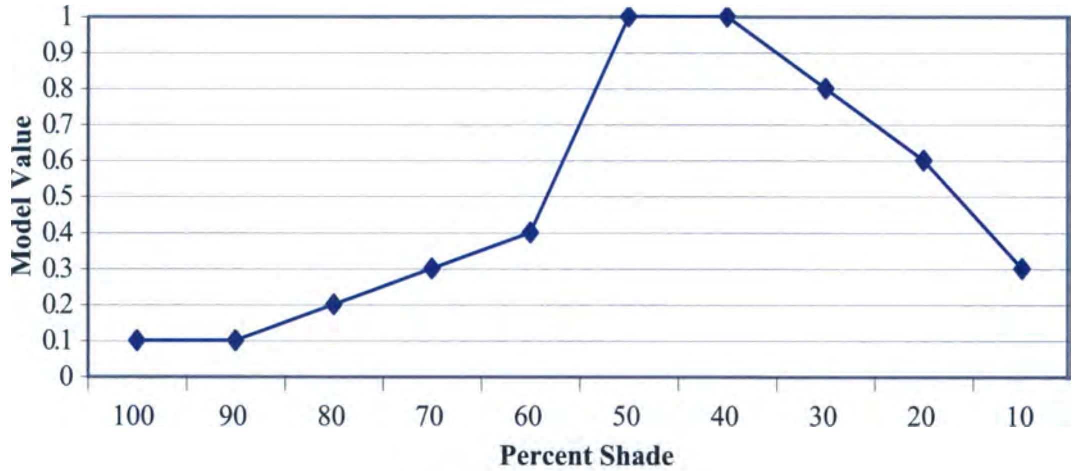

Fig. 1. Percent overstory shade.

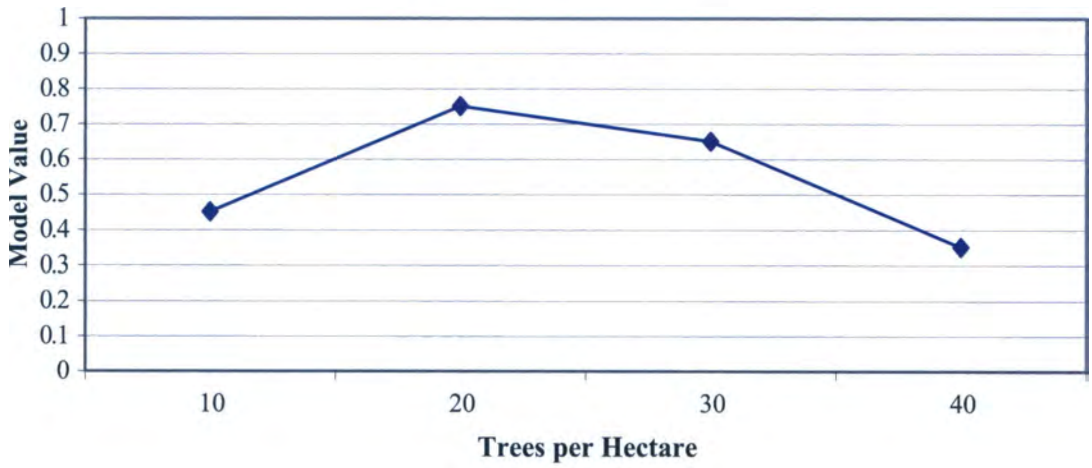

Fig. 2. Class 1 trees.

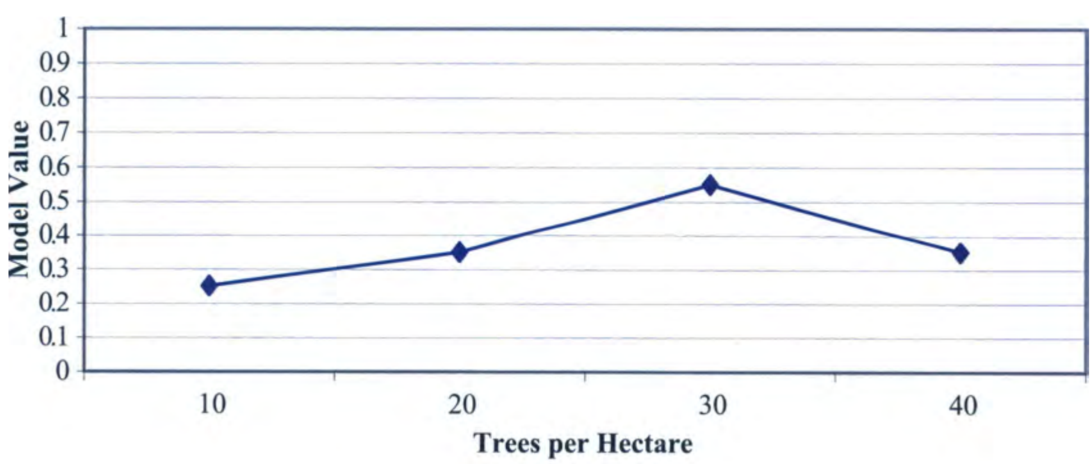

Fig. 3. Class 2 trees.

vations is provided as Fig. 2. In addition to the species listed above, the mix of the above species with hackberry (*Celtis occidentalis*) Slippery Elm (*Ulmus rubra*) and Kentucky Coffeetree (*Gymnocladius dioica*) is also favorable for presence of Running buffalo clover, but to a lesser extent as illustrated in Fig. 3. Further, the presence of Hawthorne (*Crataegus sp.*), Sycamore (*Platanus occidentalis*), Boxelder (*Acer negundo*), White ash (*Fraxinus americana*), and green ash (*Fraxinus pensylvanica*) are loosely associated with the presence of Running Buffalo Clover, but to a much less pronounced extent as shown in Fig. 4.

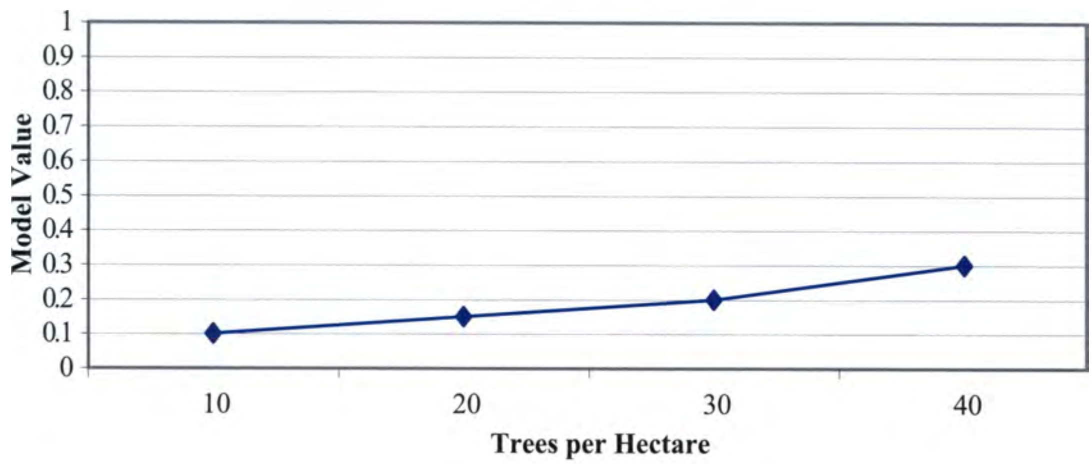

Fig. 4. Class 3 trees.

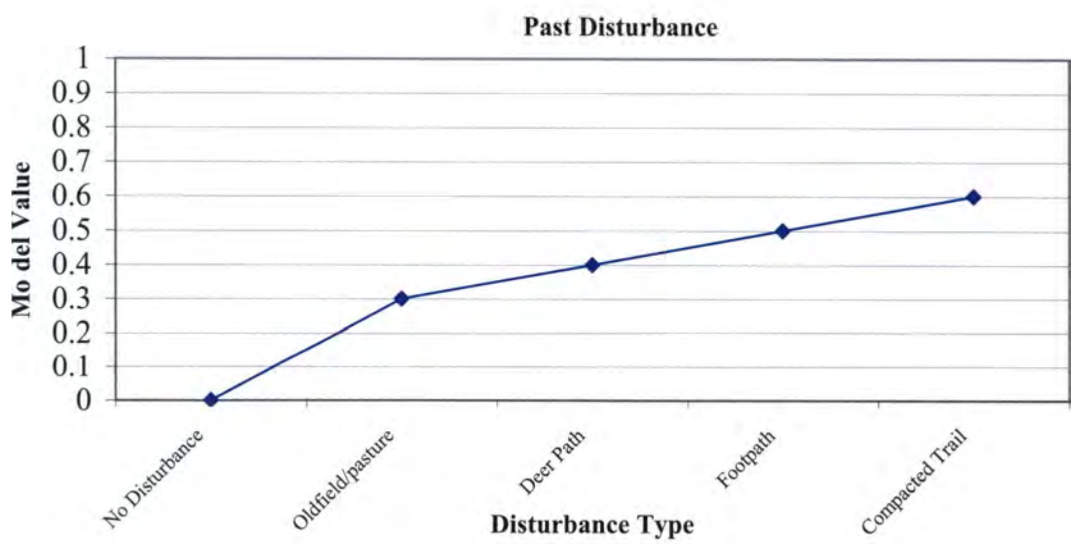

Fig. 5. Past disturbance.

Past disturbance of the site

Curiously, one of the peculiarities of Running Buffalo Clover is its association with areas that have experienced disturbance in the past (Campbell et al., 1988). The species common name is derived from the presence of this plant in association with old buffalo trails or "traces" that once crisscrossed the area where the remnant populations can be found in the present day. As a result, disturbance is of major importance to the likelihood of occurrence of this species. Disturbances were evaluated in the form of no disturbance, old field pasture disturbance, deer path and/or trail, footpaths and heavily compacted trails, with emphasis placed on the disturbance type involving noticeable compaction as shown in Fig. 5, which is a graph of this relationship.

Type of disturbance

The type of disturbance is separately considered as it relates to disturbances listed in the available species literature, and ranges from no disturbance to areas which have experienced substantial cattle or deer browsing, evidenced by well worn trail areas (Cusick, 1989) as shown on Fig. 6.

Disturbance duration

The longevity of the disturbance also seems to favor the Running Buffalo Clover, with disturbance over a long period of time favored by the species. Apparently there is some growth strategy of this species which is able to survive and flourish in areas where other aggressive species are prevented from achieving a foothold due to continual disruption or soil disturbances. Running Buffalo Clover is apparently able to thrive under these otherwise hostile conditions. This is illustrated on Fig. 7.

Soil pH

The pH of the soil is important to the propagation and development of the Running Buffalo Clover, with the optimal pH conditions being approximately neutral ranging from a pH of 7.0 to roughly 8.0 for the species presence (Becus, 1989). This is shown on graph Fig. 8.

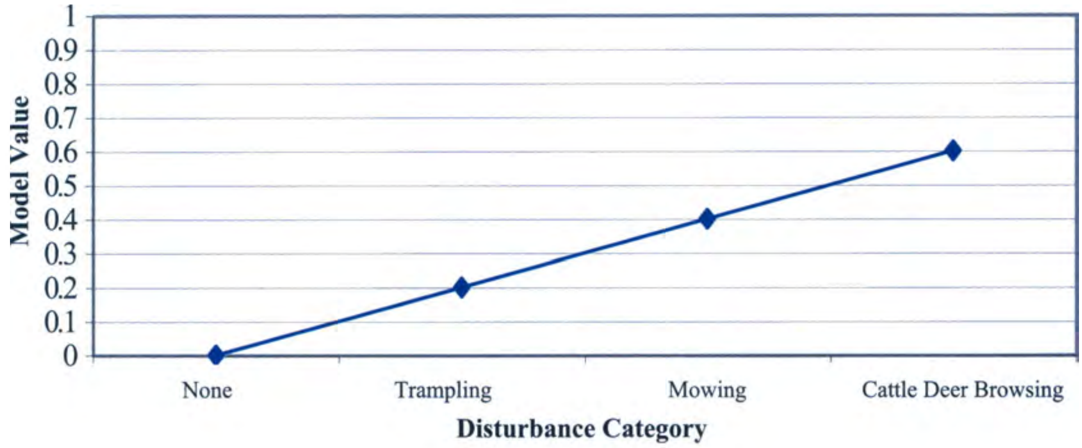

Fig. 6. Disturbance type.

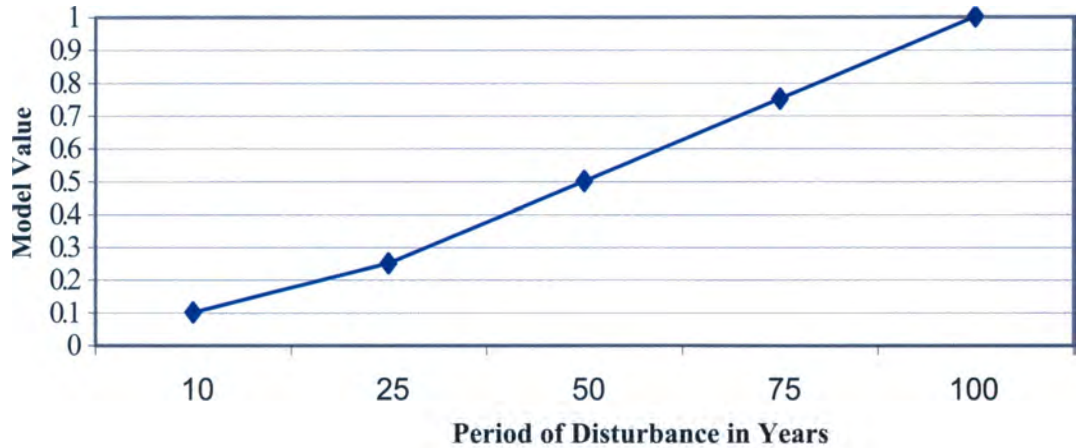

Fig. 7. Disturbance duration.

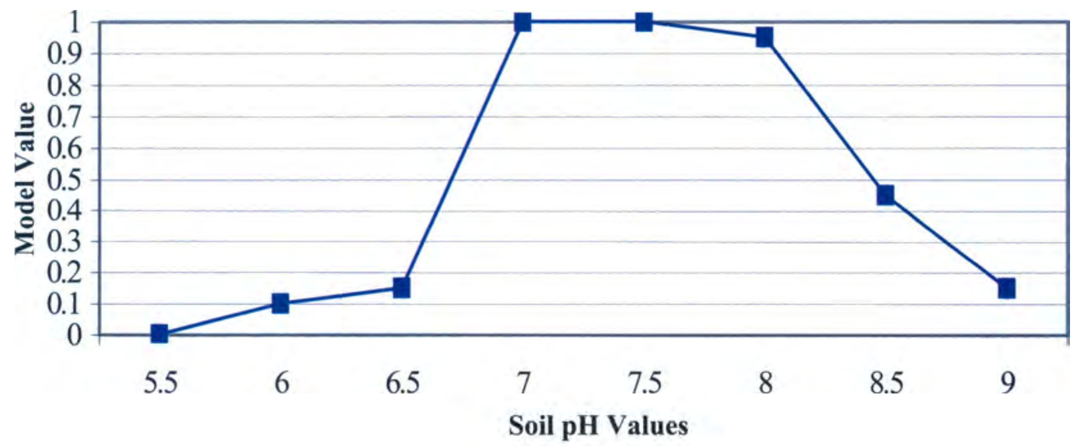

Fig. 8. Soil pH.

Soil drainage class

The drainage class for the species seems to favor well-drained site with the classifications of "well drained and moderately well drained" being the preferred growth regime for the species. The graph of this relationship based on the literature is provided as Fig. 9.

Soil type

The soil type information refers to the textural properties of the site soils. This information can be obtained most readily from county soil survey manuals and the conformed or modified based on site specific field observations made at the time of the field study. This in-

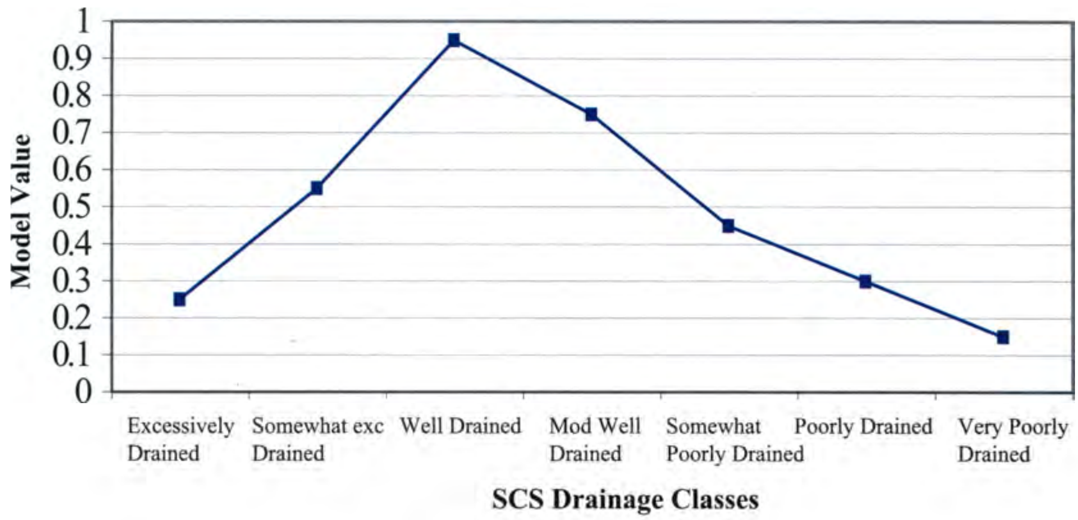

Fig. 9. Soil drainage class.

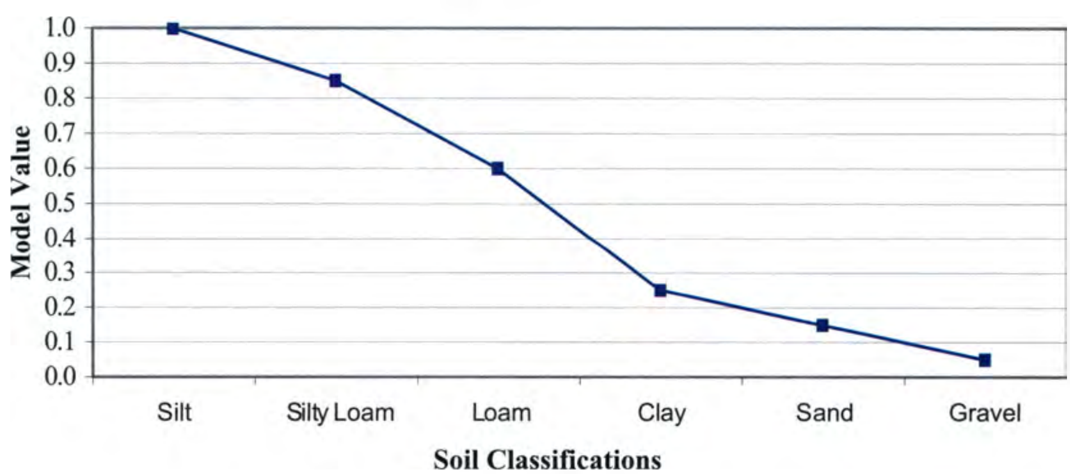

Fig. 10. Soil type.

formation is shown in Fig. 10. The literature review suggested that silts and silty loams are optimal for the presence of Running Buffalo Clover.

Landscape position

The landscape position refers to whether the site under evaluation is located on a hilltop, upper, mid or lower slope or in a floodplain position. Figure 11 indicates the relationship of the landscape position to the importance for location of Running Buffalo Clover, based on this model and field sampling results.

Site moisture regime

The site moisture regime variable relates to the effect of the slope aspect and solar exposure of the site. (Note this is distinct from the Soil Drainage Classification, which refers to a physical drainage property and not to the above-ground site moisture regime.) The difference in exposure between a north facing moist regime from a south facing dry regime is an obvious example of this relationship. For this model, the relationship between the site moisture regime and the HSI value is exhibited on Fig. 12.

HSI model computation

Determination of the habitat suitability index using the above defined field measurement variables, involved the cumulative addition of individual or group HSI score values on a per-site basis following the formula:

$$\text{Overall HSI} = \left(V1 + \frac{V2a + V2b + V2c}{3} + \frac{V3a + V3b + V3c}{3} + V4 + V5 + V6 + V7 + V8\right)\Big/8.$$

In the above HSI formula, the listed variables are the following:

V1 = Percent overstory shade;
V2a = Class 1 trees;

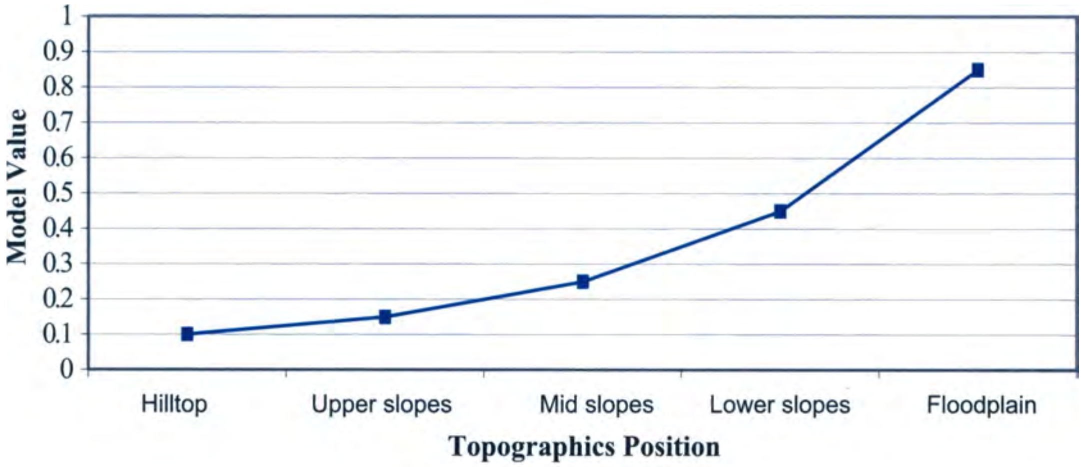

Fig. 11. Landscape position.

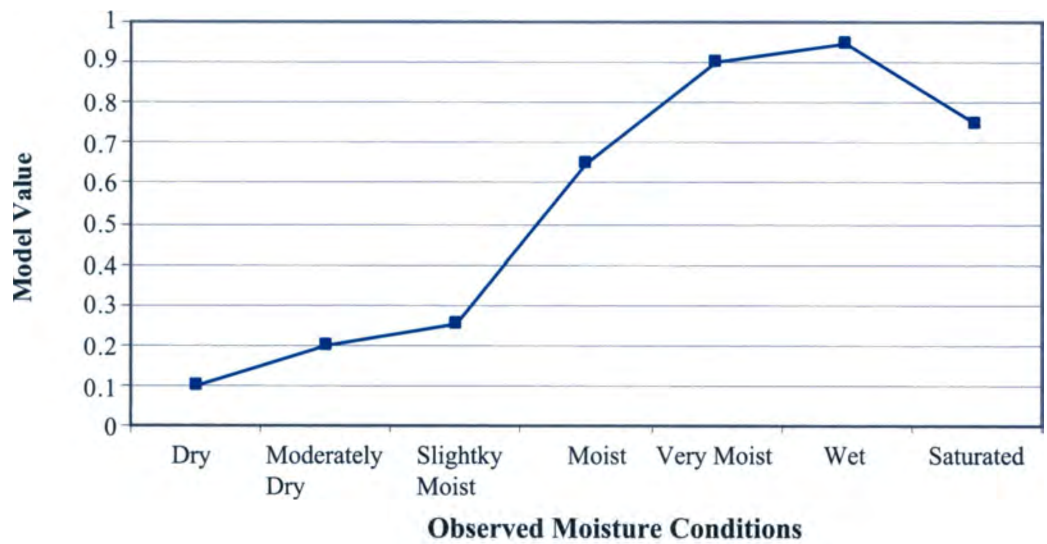

Fig. 12. Site moisture regime.

V2b = Class 2 trees;
V2c = Class 3 trees;
V3a = Past Disturbance;
V3b = Disturbance type;
V3c = Disturbance duration;
V4 = Soil pH;
V6 = Soil Drainage Class;
V5 = Soil type;
V7 = Landscape position; and
V8 = Site moisture regime.

In the above list of field variables, V2a, V2b and V2c (Tree Species Composition and Density variables) were all similar components requiring an averaged HSI value for the cumulative result of the individual observations. In similar manner the site, variables V3a, V3b and V3c concerned with past disturbance, required a single averaged HSI value for inclusion into the model. After these two subgroups were averaged, the remaining variables were cumulatively added and an average for the total of the individual HSI measurements was obtained to provide an overall HSI value.

HSI value sensitivity
The individual HSI field measurement variables, based on the information obtained from the literature accounts of the Running Buffalo Clover, were incorporated into the model and the field program was conducted for 10 individual plots spanning a three-state sampling area. Based on the results obtained and tabularized, some of the HSI variables were observed to be sensitive indicators while others were relatively insensitive components of the program.

As a check to the sensitivity of the model to this species, two sampling locations in which known populations of Running Buffalo Clover occur were used, in addition to eight other sites including undisturbed as well as existing ROW corridor areas, to determine if the species HSI model could be used to effectively predict the likelihood of occurrence of the T&E species on the basis of measuring HSI values.

RESULTS

The calculated HSI values for each of the 10 study plot areas are presented in Table 1. The individual plot areas were identified, and the individual variables were provided in table footnotes. Individual field measurement variable values obtained from each of the sites were presented and the overall values for the study program were derived as the output of the modeling program.

General results of the modeling development and assessment indicated that for Running Buffalo Clover specifically, the model represented some of the individual site specific requirements of the species to a high level of sensitivity. Specifically, Table 1 illustrates the field sampling results obtained for 10 plot sites, and the full range of field measurement variables incorporated into the model. Based on the use of the two "calibration sites" which were known to contain populations of Running Buffalo Clover, the modeling results indicated a high overall HSI score for Plot #1 and Plot #8. In addition, the remainder of the sites were represented by overall HSI values indicating a lesser likelihood for the occurrence of this sensitive species due to the combination of the individual field measurement variable scores obtained.

Individual analysis of the Field measurement variables indicated that some of the variables were very sensitive indicators for the Running Buffalo Clover, including variables V1, V2a, V3c, V5, V6, V7, V8 and to a lesser extent V3a (Table 1.) Variable V1 provided a strong indication that the presence or absence of overstory shade in the right percentage is a key indicator for the presence of Running Buffalo Clover (Fig. 13 and Table 1).

The caution that should be exercised is that an indication of strong correlation of a variable for a particular site may not lend itself to application across the full range of site conditions that apply to a particular species. The individual site conditions observed in the field for this study would suggest that reliance on as many definable characteristics of individual species variability and growth conditions as practical is a better approach to take when using the modeling method to develop an occurrence strategy for energy corridors or other potential developments.

At the same time, when noting the strong indicator variables, several variables were found to be relatively insensitive as indicators of the potential for presence of Running Buffalo Clover. These variables included V2b, V2c, V3b and V4. For these latter relatively insensitive indicator variables, it may have been the case that the overall HSI "range" shown on the individual variable graphs used in the modeling did not possess sufficient numeric range to provide for clearcut demarcations between various categories of site conditions. The example presented for Variable V2b (Fig. 14 and Table 1), which is a secondary indicator for Class 2 trees can illustrate this point (including; Hackberry, Slippery Elm, and Kentucky Coffee tree).

The low density of 10 plants per hectare to the high value of 40 plants per hectare, only results in an HSI range of 0.3 HSI units (0.25 to 0.55). Perhaps if this range were expanded to from 2 to 3 times the existing amplitude, this indicator variable would be a more sensitive representation of this tree density class. This possibility applies equally to the other insensitive indicators and in the future could be determined through sensitivity analysis and subsequently incorporated into future model refinements for this species.

DISCUSSION AND CONCLUSIONS

Based on review of the results obtained for the program and presented in Table 1, the HSI modeling approach to determination of the likelihood of occurrence of the Running Buffalo Clover on a site is a viable method for sensitive species determinations for ROW corridors and similar potential site developments. Though the use of the traditional HSI technique is well known in its application to non-sensitive endemic wildlife, its application to Threatened and Endangered species has not been well documented. The application of the technique to the presence or absence of Running Buffalo Clover within a portion of its range in the Midwest was tested in this program and exhibited potential for application to a broader range of T&E and other sensitive species.

The utilization of species specific literature to develop the modeling variable parameters and consultation with recognized species experts measurably assisted in the development of the preliminary modeling elements and identification of areas in which modeling difficulties were likely to occur. This information was used as a starting point from which the first order model was developed then defined and subsequently tested under field conditions.

Use of a known site of occurrence for a sensitive species as a "calibration site" is recommended as a technical guide for individual model development. As noted in the above study, the presence of two known sites of occurrence for Running Buffalo Clover formed a template against which the other evaluation sites used for model development could be compared. There are no doubt individual species for which this modeling application may not be suitable as the result of either widely varying site requirements, substantial "plasticity" in the species ability to adapt to widely varying conditions or unknown individual species factors which regulate the suitability of individual habitats or areas to the individual species requirements.

This modeling approach has the potential to allow for "pre-screening" of the likely occurrence of T&E species on a site, based on modeling and evaluation

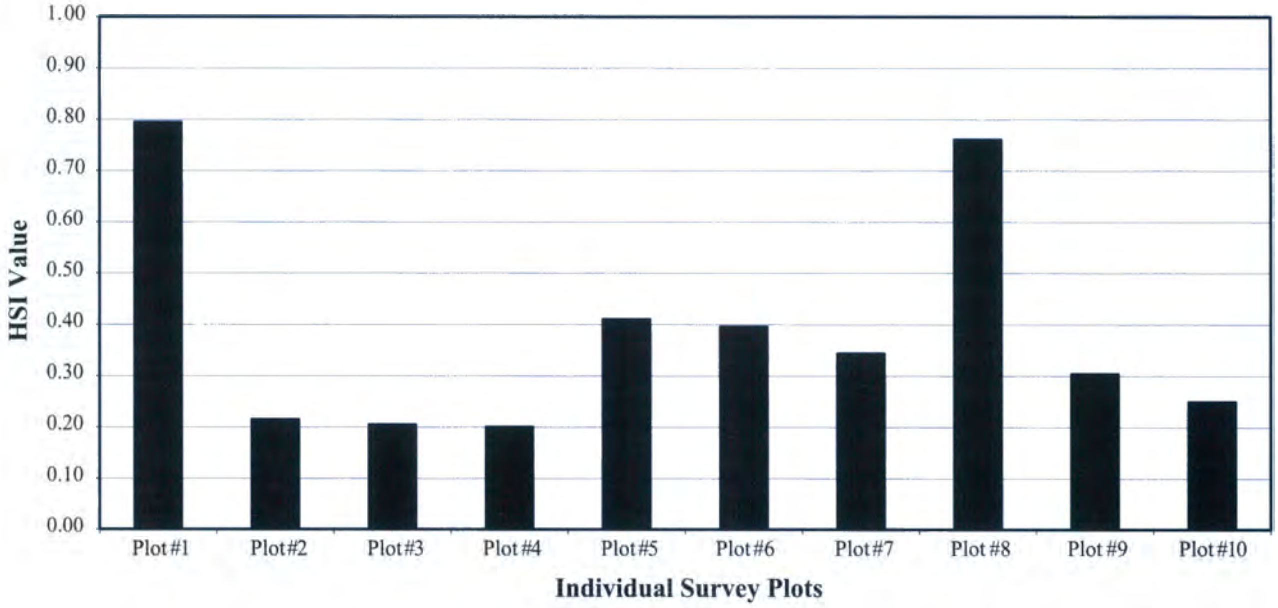

Fig. 13. Sensitive HSI indicator V1 – percent overstory shade.

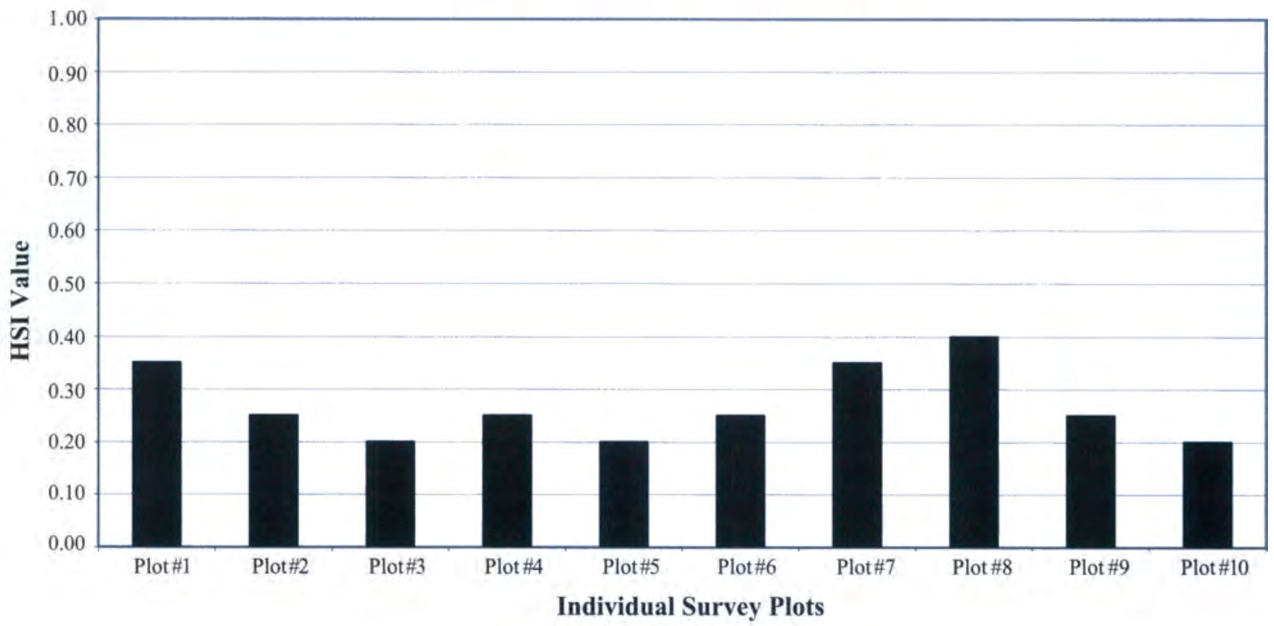

Fig. 14. Insensitive HSI indicator V2b – class 2 trees.

of site imagery and species requirements prior to conducting actual field confirmatory studies. This tiered modeling approach has potential to be more effective and economical than conventional intensive field efforts conducted without the use of a T&E species modeling method. In addition this modeling approach may be an excellent tool for screening of sites for potential use as restoration or mitigation sites involving habitat compensation programs.

Use of this HSI approach to Modeling for T&E species represents a potentially valuable evaluation tool that can be applied using existing modeling "platforms" and has immediate application to various imagery and database formats.

The author emphasizes that T&E species modeling is only as applicable and predictive as the quality of the individual species data available. Fortunately, especially for many T&E species, the database of information is usually considerable. Further individual T&E species assessments and model development and calibration studies are planned especially for regional T&E species as well as for candidate species of concern at both the state and federal levels.

REFERENCES

Avery, T.E. 1975. Natural Resource Measurements. Second edition. McGraw Hill Book Company, New York. 339pp.

Bartigis, R.L. 1985. Rediscovery of *Trifolium stoloniferum* Muhl. Ex A. Eaton. Rhodora 87: pp. 425–429.

Bartigis, R.L. 1989. Recovery Plan for Running Buffalo Clover (*Trifolium stoloniferum*). U.S. Fish and Wildlife Service, Twin Cities, MN. 26 pp.

Becus, M.S. 1989. Running Buffalo Clover Monitoring in the Hamilton County Park District, Final Report. Ohio Department of Natural Resources, Division of Natural Areas & Preserves. 32 pp.

Brooks, R.E. 1983. *Trifolium stoloniferum*, Running Buffalo Clover: Description, Distribution, and Current Status. Rhodora 85: pp. 343–354.

Campbell, J., M. Evans, M. Medley, and N. Taylor. 1988. Buffalo Clovers in Kentucky (*Trifolium stroloniferum* and *T. reflexum*): Historical Records, Pre-settlement Environment, Rediscovery, Endangered Status, Cultivation and Chromosome Number. Rhodora 90: pp. 399–418.

Cusick, A. 1988. Ohio Status Survey for *Trifolium stroloniferum* (Running Buffalo Clover). Report to the U.S. Fish and Wildlife Service, Office of Endangered Species, Twin Cities, MN. 35 pp.

Cusick, A. 1989. *Trifolium stroloniferum* (Fabaceae) in Ohio: History, Habitats, Decline and Rediscovery. Division of Natural Areas and Preserves, ODNR, Columbus, SIDA 13(4): pp. 467–480.

Davis, W. 1987. On the Decline of *Trifolium stroloniferum*. Kentucky Native Plant Society Newsletter 2(3): 10 pp.

Hale, A.M. 1980. An Optical Canopy Cover Instrument. The Ohio Journal of Science 80(3): pp. 125–128.

Hale, A.M. 1994. Construction of a Circular Plot Sampling Instrument. The Ohio Journal of Science 94(4): pp. 113–115.

Hays, R.L. 1985. A Users Manual for HEP Accounting Software for Microcomputers. Version 2. Western Energy and Land Use Team. U.S. Fish and Wildlife Service, Ft. Collins, Colorado. 117 pp.

Hays, R.L. 1987a. A Micro-HSI Master Model Library, Cover Type List and Variable Lexicon Reference Manual. Version 2. Western Energy and Land Use Team. U.S. Fish and Wildlife Service, Ft. Collins, Colorado. Various pagination.

Hays, R.L. 1987b. A Users Manual for Micro-HSI Habitat Suitability Index Modeling Software for Microcomputers. Version 2. Western Energy and Land Use Team. U.S. Fish and Wildlife Service, Ft. Collins, Colorado. 128 pp.

O'Neil, L. J., T.H. Roberts, J.S. Wakeley, and J. W. Teaford. 1988. A procedure to modify Habitat Suitability Index Models. Wildlife Society Bulletin 16: 33–36.

Schamberger, M.L. and L.J. O'Neil. 1986. Concepts and Constraints of Habitat Model Testing. Pages 5–10 in J. Verner et al., eds. Wildlife 2000. University of Wisconsin Press, Madison.

Thomasma, L.E., T.D. Drummer, and R.O. Peterson. 1991. Testing the Habitat Suitability Index Model for the Fisher. Wildlife Society Bulletin 19: 291–297.

U.S. Department of the Interior, Fish and Wildlife Service. 1981. Standards for the Development of Habitat Suitability Index Models. 103 ESM. Division of Ecological Services, USFWS, Washington D.C.

U.S. Department of the Interior, Fish and Wildlife Service. 1985. Micro-HSI Master Model Library. Release 1.2 HEP Software Support Group, Western Energy and Land Use Team. U.S. Fish and Wildlife Service, Ft. Collins, Colorado. 84 pp.

Wakeley, J.S. 1988. A Method to Create Simplified Versions of Existing Habitat Suitability Index (HSI) Models. Environmental Management 12(1): 79–73.

BIOGRAPHICAL SKETCH

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Dr. Hale is a Principal Ecologist in the URS Cincinnati office, responsible for development, design, implementation and monitoring for a range of projects involving natural resources, environmental impact statements and assessments and sensitive species investigations. His technical background includes substantial experience in ecological baseline investigations including the areas of, wetlands programs, site investigations, and predictive analysis for a wide variety of ecological study areas. Dr. Hale has used the HEP and HSI procedures on major federal EIS programs and has conducted alternatives analysis using HEP to predict various future project conditions given site-specific assumptions. Dr. Hale holds Senior Ecologist and Professional Wetland Scientist certifications and Habitat Evaluations Procedure and WET Functional Analysis technical certificates. In addition, he has analyzed and conducted model sensitivity studies for a number of recently developed HEP/HSI modeling programs.

Part VII
Geographic Information Systems

Using a Mobile GIS Platform for Management of Noxious Weeds in the Mokelumne River Watershed of Northern California

Michael E. Fry and George Ball

Long-term monitoring of natural resources at the landscape level is a challenging task. Pacific Gas and Electric Company's hydroelectric project watersheds, located throughout the Sierra Nevada Mountains of central and northern California, collectively represent tens-of-thousands of acres where ecological monitoring activities are required by the Federal Energy Regulatory Commission (FERC). Noxious weeds, and the habitats they affect, are often associated with managed linear rights-of-way that comprise elements of our hydro power systems. These elements include roads, transmission corridors, canals, and penstocks. The control of noxious weeds within FERC project boundaries is increasingly made the responsibility of the Licensee under specific Articles or Conditions of a federal project license. In this paper, we describe use of commercially available mobile computing and geographic information system (GIS) technologies used to inventory, monitor, and document control treatments for noxious weed populations within the Mokelumne River Hydroelectric Project watershed. We describe a mobile GIS platform consisting of a handheld PC with wireless global positioning system (GPS) receiver, and ESRI® ArcPad™ GIS software. Some advantages of these handheld electronic devices include the following:

1. aids navigation through GPS-enabled moving map display,
2. acquires electronic data compatible with standard office software, avoiding transcription costs,
3. synchronizes with desktop or laptop PC's for file back-up, preparation of report documents, and preparation of map figures, and
4. allows monitoring to be done by any qualified professional, regardless of their prior experience in the project area (important for long-term monitoring).

Ground photos hyperlink to their corresponding features in the GIS database. New feature documentation (point, line and polygon) is accomplished with the GPS, or on the touch screen using a stylus. Integrated electronic data forms allow highly customized documentation of feature attributes. Background map layers may consist of georeferenced USGS quads, or aerial imagery. The cost of high-resolution orthorectified imagery may be justified for most long-term environmental monitoring projects. Other hardware and software costs total approximately $2,000.

Keywords: Noxious weeds, invasive weeds, GIS, GPS, ArcGIS, ArcPad

INTRODUCTION

The transition from analog to digital representations of global geography is one of the many remarkable accomplishments of the computer age we live in (Tomlinson, 1988). Geographic information systems (GIS) have been described as databases containing spatially referenced land-related data, as well as the procedures and techniques for systematically capturing, storing, retrieving, analyzing, processing, updating, and displaying that data (Mark et al., 1997). GIS technology got started in the late 1950's and early 1960's.

Beginning in 1978, a U.S. government-sponsored satellite navigation system (NAVSTAR) was launched.

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By 1985 NAVSTAR had 10 satellites in orbit. The system came to full operational design status in 1991 with 24 orbiting satellites supporting ground capture of georeferenced data through commercially available GPS receivers. For a more comprehensive history of the development of GIS see the work by Foresman (1997).

At this point; however, GIS technology was still largely in the hands of highly trained specialists. Only since the beginning of the new millennium, have we seen development of ever smaller, ever faster personal computers (some ruggedized for field use), further improvements in GPS technology and GIS software that make mobile computing and mobile GIS solutions available to most resource management professionals.

THE MOKELUMNE RIVER NOXIOUS WEED PROGRAM

The Mokelumne River Project (FERC 137) was built and began operation in the 1920's. Its operating license was recently renewed for a thirty-year term. With the new license there came many new requirements pertaining to environmental protection. Included was Condition 17, the result of a formal recommendation to FERC by the Eldorado National Forest under Section 4(e) of the Federal Power Act, that requires PG&E to inventory, control, and monitor noxious weeds over nearly 7,000 acres of watershed lands, annually, for the term of the new license (30 years). These lands are a combination of National Forest System Lands and PG&E fee title properties contained largely within the FERC boundary of the project.

The following brief discussion will serve to provide a biological and policy context for Condition 17.

Biological context

Highly invasive noxious weeds (e.g., yellow star thistle, *Centauria centaurea solstitalis*) can negatively impact many resources including native vegetation, soils, wildlife and wildlife habitat, rangelands, and the recreational quality of our public lands (USDA, 2001). The following list is based on information presented in the Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement and Record of Decision (USDA Forest Service, 2001):

1. When populations of invasive non-native plants dominate wildland sites, the ability to manage for healthy ecosystems is compromised or eliminated. One of the most immediate effects of weed invasion is the displacement of native plants. When the complex mix of native plants in an ecosystem is replaced by non-native aggressive weed species, the impacts reverberate throughout that ecosystem;
2. Weed infestations are frequently accompanied by increases in erosion and runoff. Soil organic matter and available nitrogen decrease when topsoil is lost to erosion. In addition, soil moisture reserves can be dramatically lowered in weed-infested areas, contributing to poor survival or failure of young forest trees;
3. A rapid shift from a native plant community to a monoculture of noxious weeds can remove forage, cover, and shelter for native animal species;
4. Livestock forage can be reduced between 35 and 90 percent on weed-infested rangelands (USDI 1985, as referenced in USDA, 2001); and
5. Recreation can be limited or curtailed altogether in areas infested by noxious weeds. Recreational activities such as hiking and camping are no longer pleasant or feasible in areas overtaken by spiny noxious weeds (e.g., Himalayan blackberry).

Policy context

Several key local, regional and national policy directives have helped to shape the current management direction concerning control of noxious weeds on National Forest System Lands.

The Sierra Nevada forest plan amendment final environmental impact statement and record of decision (USDA, 2001)

Known as the Sierra Nevada Framework, this document provides direction and policy as well as standards and guidelines for management activities on National Forests in the Sierra Nevada. With respect to noxious weeds, the Sierra Nevada Framework set forth the following:

1. Incorporates priorities set forth in Forest Service Manual 2081.1;
2. Implements Standards and Guidelines "As outlined in the Regional Noxious Weed Management Strategy, when new small weed infestations are detected, emphasize eradication of these infestations while providing for the safety of field personnel";
3. Implements an Aquatic Management Strategy (AMS), the purpose of which is to retain, restore, and protect habitats for aquatic and riparian-dependent organisms and to produce and deliver high-quality waters; and
4. Designates Riparian Conservation Areas, with site-specific analysis, to determine the impact of proposed management activities on Riparian Conservation Objectives.

Pacific southwest region noxious weed management strategy (2000)

The PSW weed strategy implements goals to reduce the spread of noxious weeds, including: integrated weed management (emphasizing eradication of new, small infestations while providing for the safety of field personnel), inventorying weed infestations, consideration of noxious weeds in project planning, prevention and detection plans, local education and awareness programs, coordination with other agencies and organizations, monitoring, and research.

The Forest Service Manual (FSM 2080)
The latest revision of the Forest Service Manual contains specific direction and policy on the management and coordination of noxious weed activities. The specific objectives in FSM 2080.2 include: prevention of the introduction and establishment of noxious weed infestations; containment and suppression of existing noxious weed infestations; formal and informal cooperation with state agencies, local landowners, weed control districts and boards, and other federal agencies in the management and control of noxious weeds; and education and awareness of employees, users of National Forest System lands, adjacent landowners, and State agencies about noxious weed threats to native plant communities and ecosystems. Where funds and other resources do not permit undertaking all desired measures, prevention and control measures outlined in FSM 2081.2 require addressing and scheduling prevention and control measures in the following order: 1) prevent the introduction of new invaders; 2) Conduct early treatment of new infestations; and 3) contain and control established infestations.

Presidential executive order on invasive species (February 3, 1999)
This executive order, signed by President Clinton, directs federal agencies to prevent the introduction of invasive species, provide for their control and to minimize the economic, ecological, and human health impacts from these species on federal lands.

The Forest Service strategy for noxious and non-native invasive plant management (USDA Forest Service 1998)
This Nation-wide Forest Service policy provides a roadmap for preventing and controlling the spread of noxious weeds and non-native invasive plants by implementing the following goals: 1) establish and maintain a prevention and education program to minimize the spread of weeds; 2) enter into cooperative weed management with other agencies, landowners, the general public, and Forest Service permittees; 3) systematically inventory and map weed infestations; 4) use an integrated approach to weed control with consideration of the best combination of treatments (chemical, biological, mechanical, and cultural) for each specific situation; and 5) effectively monitor weed spread and treatment success.

Memorandums of understanding establishing noxious weed management areas in Eldorado, Placer, Alpine, and Amador counties
Under these memoranda the Eldorado National Forest generally agreed to: educate the public about noxious weeds and assist in identification of methods for weed control; promote the control and treatment of noxious weeds on federal lands; support and assist other agencies and interested parties in noxious weed prevention and control; and identify and map all noxious weed infestations on National Forest System Lands.

Like most hydroelectric power projects, the Mokelumne River project includes among its operating facilities a variety of linear corridors including project roads, canals, penstocks, and both distribution voltage and transmission voltage over-head electrical lines. The development and maintenance of these facilities results in conditions that favor establishment and spread of weeds, and human activity throughout the project area results in the continual introduction or reintroduction of weed seeds to the watershed.

METHODS

The specific language of License Condition 17 requires inventory, control and monitoring of noxious weeds on all Forest Service lands within the FERC project boundary and adjacent PG&E fee title property. Therefore, our first goal was to create a weed survey boundary shape file to define these lands (Fig. 1), and use this to guide the work of our field crews during baseline surveys. PG&E's GIS staff in San Francisco accomplished this using desktop GIS software and a procedure called "intersection." Once created, this boundary became the defining element of our program area. Field surveys considered 100 percent of the area within the survey boundary as shown in Fig. 1. Some areas (e.g., open water, bare-rock outcrops) were eliminated for lack of suitable habitat conditions.

The baseline inventory of noxious weeds was performed for PG&E in 2002, by LSA, Associates of Point Richmond and Irvine, California. Our iPAQ platform was not yet operational at that time, therefore, the consultants utilized a Trimble™ GPS receiver, and collected attribute data using PenMap® software running on a notebook computer. All weed features (point and polygon shape files), were later transferred to the new ArcPad map file on the iPAQ.

The moving map display is created by linking a GPS receiver to the mobile device. The receiver acquires a data stream from the constellation of overhead satellites and sends a signal to the mobile device which displays a location symbol on the view screen. When activated against a background layer (e.g., weed survey boundary) the user sees their current position relative to spatially referenced features or images. A moving map display aids navigation and insures that time in the field is spent as efficiently as possible. PG&E currently is using a wireless (Bluetooth™ enabled) GPS receiver manufactured by Socket™ for ArcPad field applications.

By adding additional background layers (e.g., georegistered topographic maps and aerial imagery; updated roads) navigation is further enhanced, and task planning in the office or field can include consideration of many more factors (e.g., difficulty of terrain, potential obstacles, distance from roads, patterns of vegetation coverage, areas of disturbance, etc.). Our platform includes a roads layer provided by the El-

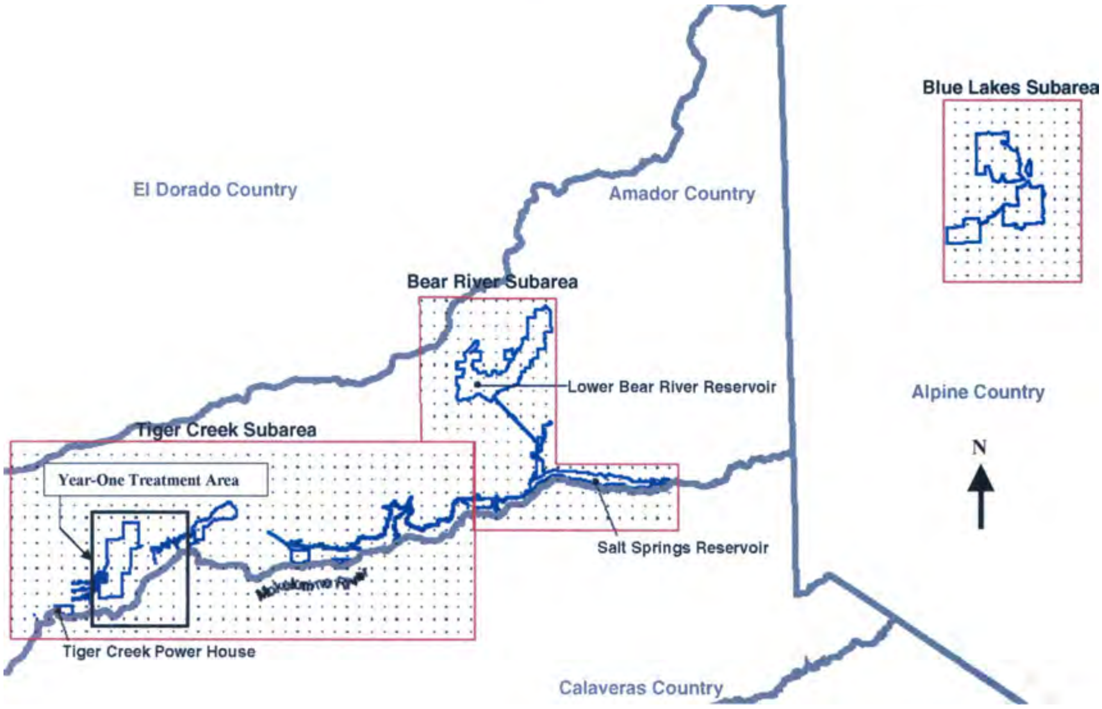


Fig. 1. Weed survey area boundary totaling 6,700 acres, Mokelumne River Project, north-central Sierra Nevada Mountains, California.

dorado Forest, and image layers consisting of USGS topographic map coverage as well as orthographic aerial photo coverage (black and white; 1 pixel = 1 square meter resolution). The image layers used in the Mokelumne platform were obtained from existing commercial sources and were then formatted and compressed for use in the mobile GIS platform by PG&E's GIS staff.

To streamline the process of data entry, ArcPad supports use of customized data entry forms created using proprietary ESRI™ software called Application Builder®. The authors collaborated on the development of custom noxious weed data forms using Application Builder. In addition to facilitating capture of a wide variety of data, these forms include drop-down lists to expedite data entry and reduce errors. Further customization allows auto-population of certain data fields. For example, when a weed's common name is selected from a drop list, its scientific name and current rating under three weed rating systems is provided automatically. This is possible because of the way ArcPad uses relational database techniques to link and index user-defined data tables stored with the program files.

RESULTS

A total of 18 noxious weed species were observed and mapped in the project area in 2002 (Table 1), ranging in elevation from approximately 3,000 to over 8,000 feet. Weed species ranged from highly invasive, able to cause considerable ecological damage in natural habitats (e.g., yellow star thistle, perennial pepperweed), to less invasive, primarily of concern as agricultural or ruderal pests (e.g., field bindweed, sweet clover). Several species were found to be relatively widespread throughout the project area (e.g., bull thistle, cheat grass, Himalayan blackberry, Klamathweed, ripgut brome, and wooly mullein). Other species occurred in one or two highly localized infestations (e.g., black locust, milk thistle, medusahead, oblong spurge, ox-eye daisy, perennial pepperweed, rush skeletonweed, and tall fescue).

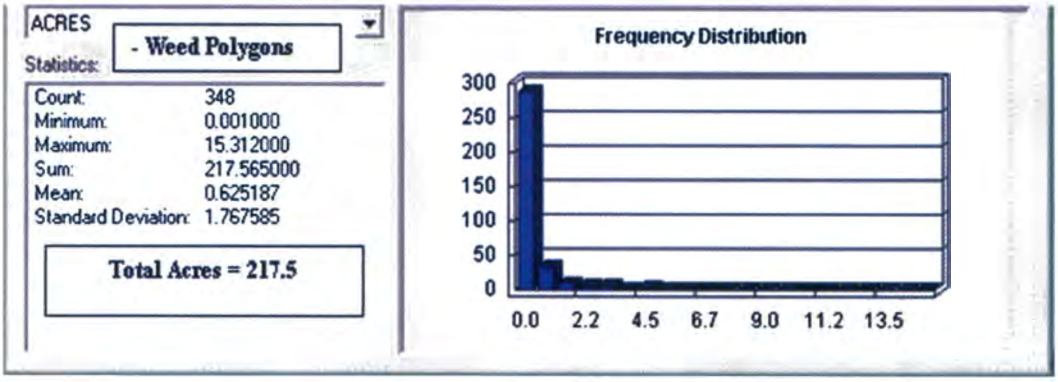
Table 1 presents each noxious weed species found during the field surveys and identifies elevation range, land ownerships (i.e., PG&E or U.S. Forest Service), frequency of occurrence, and extent of each weed species infestation. In all, a total of about 670 occurrences were documented and mapped. A final report of baseline surveys was prepared for PG&E by LSA, Associates in April of 2003. This report was submitted to and approved by the Eldorado Forest, and served to facilitate further discussion between PG&E and the Forest concerning strategies for control of noxious weeds in the project area. Collectively, target weeds comprised a total of less than 300 acres of infestation over the entire survey area, with most species populations involving small, widely scattered occurrences (Fig. 2).

It was eventually agreed that control measures were not practical for several of the species identified during the baseline surveys, including some with extensive distribution within the project area. Two species of annual grass, rip-gut brome and cheat grass are too widespread and too easily reintroduced into the project area to be successfully controlled. Himalayan blackberry is in large part distributed along stream banks and reservoir shorelines. The Forest Service would not authorize

Table 1. Noxious weeds observed and mapped within the Mokelumne River Project Weed Survey Boundary during baseline inventories conducted in 2002

Species	Suitable habitat/ elevation (feet)	Parcel ownerships where species occurs[i]	Relative frequency of occurrence
Bromus diandrus Ripgut brome	Scrub, grassland. <4,000 feet	USFS, PGE	122 locations encompassing 7.88 acres
Bromus tectorum Cheat grass	Sagebrush, pinyon-juniper and desert communities, <8,000 feet	USFS, PGE	151 locations 3.04 acres
Centaurea melitensis Tocalote	Fields, open woods; CA-FP.[ii] <4,000 feet	USFS	4 locations encompassing <0.01 acres
Centaurea solstitialis Yellow starthistle	Grassland, woodland; CA-FP. <3,000 feet	USFS, PGE	2 locations encompassing 0.03 acres
Chondrilla juncea Rush skeletonweed	Disturbed ground in many plant communities; Coast ranges, SN,[iii] Great Valley. <600 feet	USFS	1 location encompassing 0.14 acres
Cirsium vulgare Bull thistle	Grassland, openings in woodland, fields, riparian areas; CA-FP. <8,500 feet	USFS, PGE	67 locations encompassing 3.44 acres
Convolvulus arvensis Field bindweed	Agricultural lands and ruderal areas, <3,500 feet	USFS	1 location encompassing 0.18 acres
Euphorbia oblongata Oblong spurge	Predominantly in Great Valley; also in SN. <4,000 feet	PGE	2 locations encompassing 0.10 acres
Festuca arundinacea Tall fescue	Disturbed places, wetlands; CA-FP. <3,500 feet; generally <1000 feet	USFS	1 location encompassing <0.01 acres
Hypericum perforatum Klamathweed	Disturbed places, pastures, meadows, woodland; mostly north & central CA. <6,000 feet	USFS, PGE	68 locations encompassing 0.08 acres
Lepidium latifolium Perennial peppergrass	Inland marshes, riparian areas. Potential to invade montane wetlands. <3,500 feet	PGE	1 location encompassing <0.01 acres
Leucanthemum vulgare Ox-eye daisy	Grassland; north & central SNH[iv] <6,000 feet	PGE	1 location – a single plant
Melilotus spp. Sweet-clover	Disturbed areas, CA-FP. <6,000 feet	USFS, PGE	8 locations encompassing 0.04 acres
Robinia pseudoacacia Black locust	Disturbed lands, riparian areas: CA-FP esp. around old homesteads. <3,500 feet	PGE	1 location encompassing, <10 trees
Rubus discolor Himalayan blackberry	Riparian areas, marshes, oak woodland. <4,000 feet	USFS, PGE	57 locations encompassing 2.54 acres
Silybum marianum Milk thistle	Waste places, pastures. <4,000 feet	PGE	1 location encompassing <0.01 acres
Taeniatherum caput-medusae Medusa-head	Grassland, oak savanna/woodland, chaparral, especially on poorly drained soils. No. Coast Ranges, SNF[v], Cascades, Great Valley, <4,000 feet	USFS, PGE	10 locations encompassing 0.05 acres
Verbascum thapsus Woolly mullein	Moist meadows, creeks, sagebrush, pinyon-juniper woodland. <8,500 feet	USFWS, PGE	18 locations encompassing 0.14 acres

[i]USFS = lands owned by U.S. Forest Service; PGE = PG&E fee title lands.
[ii]CA-FP = California Floristic Province (California except for desert regions).
[iii]SN = Sierra Nevada.
[iv]SNH = Sierra Nevada high elevations.
[v]SNF = Sierra Nevada foothills.



Note: *X* axis shows population size in acres, *Y* axis shows numbers of populations. The majority of weed populations found were very small in total area.

Fig. 2. Weed polygon size and frequency distribution, Mokelumne River Project weed control program.

use of herbicides in these areas, and mechanical removal would have resulted in substantial disturbance to aquatic habitats.

It was also agreed that weed control efforts over the program area would occur sequentially over a period of four-years, each year targeting a new portion of the 6,700 acre control program area. Monitoring of control effectiveness will begin the first year following treatments in each area and will continue annually thereafter.

In the fifth year, a new comprehensive baseline inventory will be performed to assess current conditions, and map new populations that may have developed since the 2002 surveys.

The first treatment applications began in spring 2004, and occurred over an area of approximately 1,200 acres. The GIS platform was used to define the year-one target area, sort out species that were no longer control targets, and to produce maps and information tables useful to the weed control contractor during treatment work. The Forest approved the use of herbicides for control of 6 out of twelve noxious weed species occurring on National Forest System Lands within the first-year treatment area; the balance will be controlled with manual/mechanical methods. The platform performed exceptionally well and was successfully used to direct all work activities in the field.

DISCUSSION AND CONCLUSIONS

The first mobile platform used in the Project area (PenMap with Trimble GPS receiver) was capable of greater precision owing to the design of its GPS receiver and the opportunity to use proprietary Trimble software (Pathfinder®) to post-process the satellite data. However, the ease of use of this system on and off-road is not as great as the iPAQ system with small, wireless GPS receiver. In addition, the cost of the earlier system (estimated at around $10,000, hardware only) was considerably greater than the cost of the current platform (approximately $2,000, includes software).

The ability afforded by these mobile GIS platforms to navigate across large landscape areas with moving map displays, and exercising other navigational options provided by ArcPad in seeking a specific target, is particularly advantageous when doing resource monitoring involving small scattered populations of plants.

Use of high resolution (1 pixel = 1 sq. ft) photographic coverage can result in some cost savings created by the opportunity to establish features, with confidence, by hand on the touch screen using a stylus rather than walking polygon perimeters with a GPS. For long-term projects, the cost may be justified but for smaller short-term projects this kind of background layer may be too expensive to justify. We have contracted aerial photographic services to obtain high resolution imagery for several of our project watersheds with costs to completion of the platform-ready imagery running from $30,000 to nearly $50,000 per project. Commercial sources of ready-to-use orthorectified imagery are available for various regions of the Country, including both color and black and white. Image resolution is usually from 1 square meter to 2 square meters.

The ability to conveniently carry to the field an electronic database of information on resource features, as well as ground-level photographs linked to these features, creates an extraordinary capability for efficient, effective resource monitoring. The ease with which attribute information and feature geometry can be edited in the field further adds to this capability.

Customization options available to ArcPad from the companion software product, Application Builder, allow greater speed and accuracy of data entry which saves time and reduces project costs. These features also contribute to greater standardization of the data and fewer data entry errors.

Lastly, long-term projects inherently involve a certain turnover in personnel that can be very disruptive when projects have relied on "institutional memory." Mobile GIS technology is fairly user friendly and does not require specialized training to use beyond normal computing skills. This makes for more seamless transition during workforce changes and helps secure the content and integrity of large data sets.

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- Condor Earth Technologies, Sonora, CA;
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REFERENCES

Foresman, T.W. 1997. The history of GIS (Geographic Information Systems). Pearson Education, 416 pp. ISBN: 0138621454.

Mark, D.M., N. Chrisman, A.U. Frank, P.H. McHaffie, and J. Pickles. 1997. The GIS History Project. www.geog.buffalo.edu/ncgia/gishist/bar_harbor.html.

Tomlinson, R.F. 1988. The impact of the transition from analogue to digital cartographic representation. The American Cartographer 15 (3), 249–261.

USDA, Forest. 1985. Land and Resource Management Plan, Eldorado National Forest. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.

USDA, Forest. 2001. Sierra Nevada Forest Plan Amendment, Final Environmental Impact Statement. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.

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Part VIII
Wetlands

Research of Wetland Construction and Mitigation Activities for Certificated Section 7(c) Pipeline Projects in the United States

James Martin, Kathleen R. Miller, and J. Roger Trettel

The Federal Energy Regulatory Commission (FERC) undertook this study to evaluate the effectiveness of the wetland provisions in the 1994 "Wetland and Waterbody Construction and Mitigation Procedures" (1994 Procedures) and to determine if natural gas pipeline companies were successful in restoring wetlands following pipeline construction. Under the 1994 Procedures, FERC's success criteria requires that the post-construction wetlands have at least 80 percent vegetative cover by native species, that the plant diversity of the restored wetland be at least 50 percent of the pre-construction condition, and that the wetland satisfies the requirements of the current federal methodology for identifying and delineating wetlands. A total of 960 wetlands from 6 distinct ecoregions throughout the United States were evaluated to identify overall success rates and to identify trends that could be attributed to wetland restoration success or failure. Trends analysis revealed the 1994 Procedures generally are successful in achieving restoration success; however, wetlands located in the eastern and mid-western ecoregions had a statistically greater success rate than those in the western ecoregions. Variables related to climate and post-construction human disturbance seem to have the greatest effect on relative success/failure of wetlands.

Keywords: Wetlands, post-construction, monitoring, FERC Procedures, mitigation, restoration

INTRODUCTION

In 1994, the Federal Energy Regulatory Commission (FERC)[1] established guidelines for minimizing wetland impacts during construction of natural gas pipelines by issuing the "Wetland and Waterbody Construction and Mitigation Procedures." Adherence to the measures prescribed in the 1994 Procedures generally is considered by the FERC staff to be the baseline (minimal) wetland mitigation appropriate for construction of natural gas pipeline projects.

Since issuance of the 1994 Procedures, the FERC generally has required all jurisdictional pipeline construction projects to adopt the 1994 Procedures, or similar approved, company-identified procedures that offer a comparable or greater level of environmental protection. The FERC staff has gained valuable insight into the effectiveness of the 1994 Procedures through their ongoing construction inspection program. However, attempts to quantify the effectiveness of the 1994 Procedures in relation to wetland restoration had not previously been examined. The FERC initiated this study to evaluate the long-term effectiveness of the 1994 Procedures and to determine if changes to the 1994 Procedures are warranted.

STUDY OBJECTIVES

Five objectives were established to meet the goal of determining if the 1994 Procedures were facilitating successful restoration of wetlands, as follows:

1. Compile information from pipelines and wetlands in diverse regions of the United States;

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1 The views and opinions expressed in this paper are solely those of the authors, and do not necessarily represent the views of the Commission or its individual members.

2. Examine wetlands of various cover types in approximate proportion to their abundance in that region of the country;
3. Examine the influence of physical factors on the success of wetland restoration, including hydrology, landscape position, soil textural class, subsoil/topsoil mixing, etc.;
4. Examine the significance of human-caused factors on success of wetland restoration, including improper construction and restoration techniques, and post-construction disturbances such as all-terrain vehicle (ATV) traffic, agriculture, logging, or residential/commercial development; and
5. Document trends in post-construction vegetation communities.

An initial aspect of the study was to establish the quality and quantity of existing post-construction monitoring data previously compiled by pipeline companies. Depending on these data, a set of regionally diverse pipeline projects, certificated after the issuance of the 1994 Procedures (December 1994), were selected for inclusion in the study.

The project also included design and application of a specially designed Microsoft© Access Database (Database) for managing and analyzing all data collected for the study. A unique data form was created to facilitate the timely collection of the data. The data form was designed to operate on a handheld field computer (PDA device) and to allow for easy transfer to the Database. Data were to be analyzed to identify trends associated with successful and unsuccessful wetland restoration. These trends were to be analyzed to allow a critical review of the 1994 Procedures and their implementation by the natural gas industry, and to identify whether modifications to the 1994 Procedures may be warranted to improve wetland restoration success.

METHODS

Data sources

An original directive of the project was to use existing monitoring data previously compiled by individual pipeline companies to the greatest extent possible. Upon review of available existing monitoring reports, however, it was determined that these reports were not complete, or not appropriately consistent to allow for quantitative analysis and comparison. Consequently, the project team determined a complete set of newly collected, and consistent, field data would be required.

This approach proposed collection of all new field data to ensure a standardized data set for all wetlands surveyed. Additionally, to account for the pre-construction condition of a wetland on a right-of-way (ROW), a reference wetland would also be sampled. The reference wetland would be an undisturbed portion of the same wetland located adjacent to the construction ROW, but not affected by construction. Best professional judgment would be used to select a reference wetland site that would best represent the on-ROW wetland's pre-construction conditions.

This approach ensured that consistent qualitative and quantitative survey methods, criteria, and methods of analysis were applied to the study. New data would be collected from pipeline projects sampled from major ecoregions throughout the United States. For maximum efficiency, pipeline projects to be sampled would be based on location within ecoregions, length of ROW, number of total wetlands along ROW, and access considerations.

Study design and site selection

A fundamental component of the study design was to evaluate projects from different regions throughout the United States and to evaluate differences in restoration results throughout the country. The Team determined that Robert G. Bailey's Ecoregions of the United States (Fig. 1) best represents the different climate zones within the conterminous United States and would yield the most meaningful results from an ecological perspective. In this system, ecoregions (regions of ecological significance) are mapped based on climate and vegetation. The result is a hierarchy containing 3 levels, domains, divisions, and provinces. Domains and divisions, the two broadest levels, are based on large ecological and climatic zones. The third level, provinces, is based on vegetational micro features. There are 4 domains, 13 divisions, and 52 provinces within the United States.

The *division* ecoregion level (Fig. 2) was selected as the most appropriate for meeting study objectives. This was due largely to the logistics of collecting data sets large enough to allow meaningful analyses in 52 *provinces* and the limitations associated with evaluating only four domains, two of which (Polar and Humid Tropical) were likely to have very few, if any, pipeline projects to survey.

The "Ecoregions of the United States" map (revised 1994) was obtained in ARC/INFO (GIS format) at a scale of 1:7,500,000 (1 inch = 118 miles) from the U.S. Forest Service. Overlaying the 117 pipeline projects identified by the FERC on the ecoregion map, the Project Team determined that 6 of the 11 division-level ecoregions were well represented: Warm Continental, Hot Continental, Subtropical, Prairie, Temperate Steppe, and Mediterranean. Further, it was concluded that a minimum of 80 wetlands per division would be required for a valid sample size, such that a total of 480 wetlands on ROW, and 480 reference wetlands (960 total) were proposed for monitoring in the 6 major ecoregions across the United States.

Projects were selected based on those with the maximum number of affected wetlands and those within reasonable geographic proximity to other pipeline projects; so that the necessary 80-study area and 80 control wetlands per ecoregion could be efficiently surveyed.

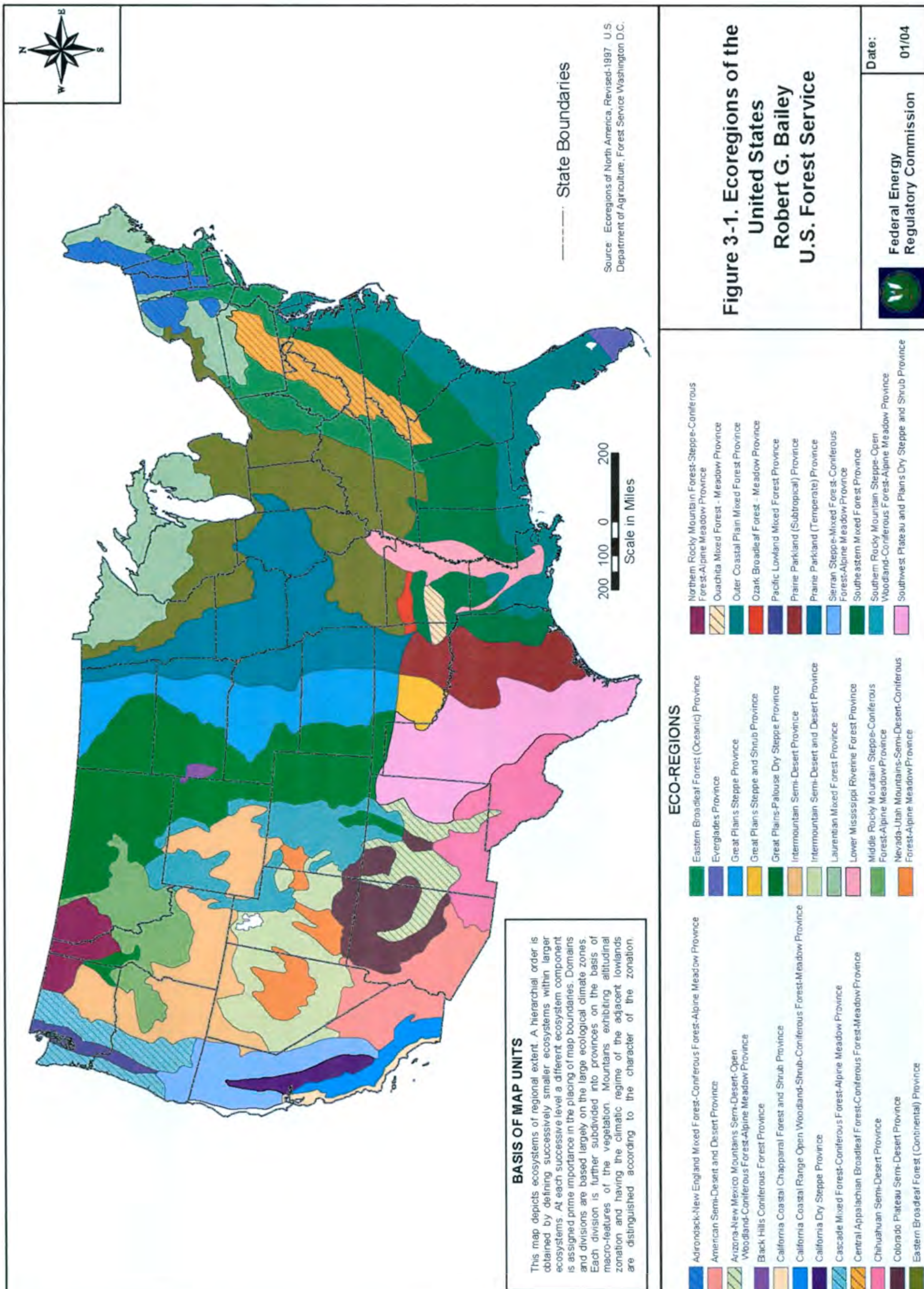

Fig. 1. Ecoregions of the United States. Robert G. Bailey, U.S. Forest Service.

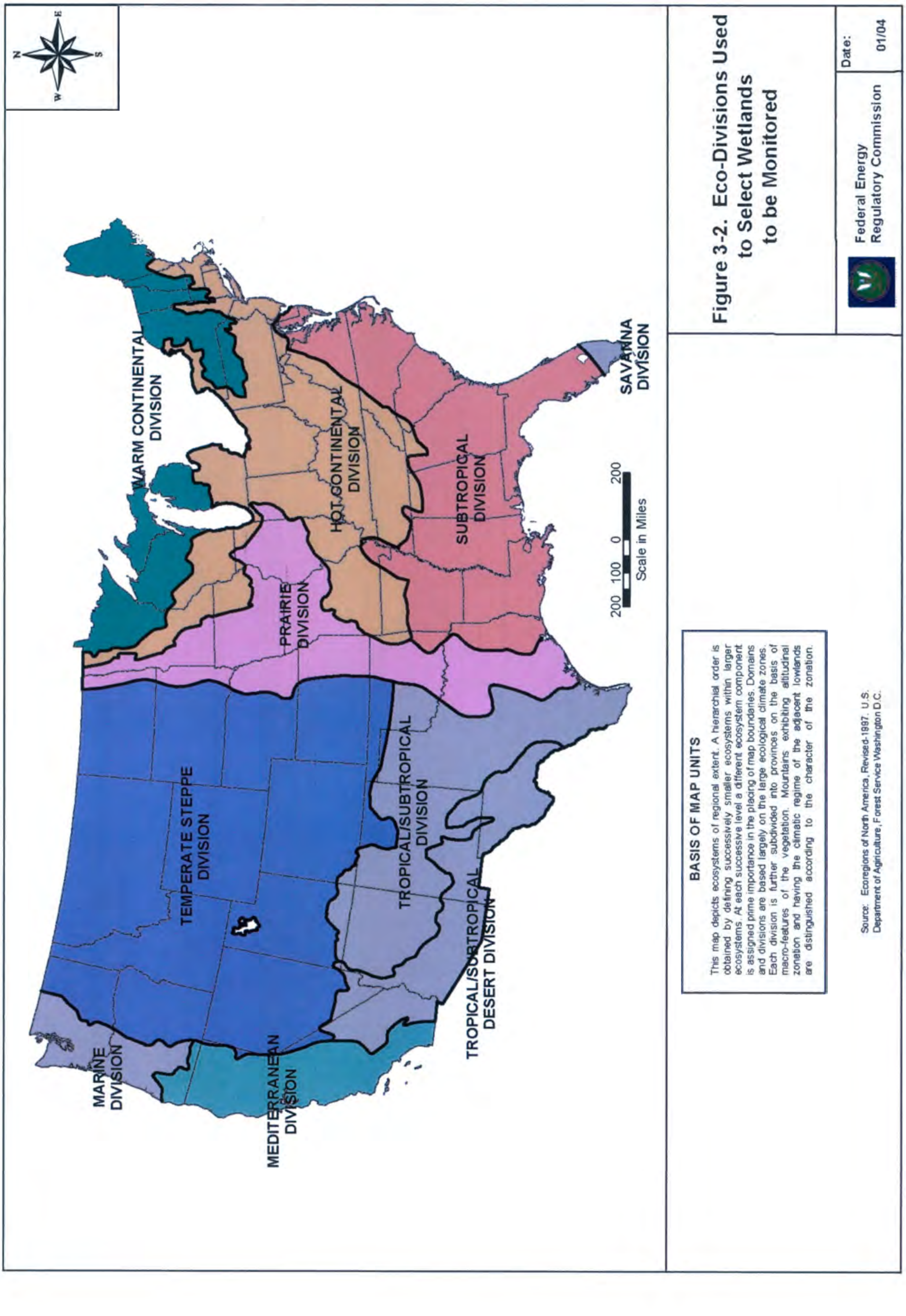

Fig. 2. Eco-Divisions used to select wetlands to be monitored.

Vegetation sampling and right-of-way characterization

A number of biological and physical parameters were identified that were critical for determining success of wetland restoration and for providing insight into the other study objectives. These parameters were measured using both qualitative and quantitative sampling methods, as described below.

Qualitative assessment

Qualitative assessments included a general site reconnaissance of the wetland and visual assessment of the overall condition of the site. Visual observations were made and recorded on a variety of variables, including: surface grade, hydrology (surface water and drainage patterns), soil type, dominant plant species, vegetative cover, vegetation vigor, community composition, presence of stump resprouting, evidence of nuisance weed invasion, residual construction impacts (waterbars, construction debris, rock fragments, and topsoil and subsoil mixing), and land use impacts (off-road vehicle damage, erosion, farming, and residential or commercial construction).

Similar data were also collected for a "matching" reference wetland. The selected reference wetland was an undisturbed portion of the same wetland located adjacent to the construction ROW. For both the on-ROW and reference wetlands, observations were documented on the data form, sketches were recorded, digital photographs were taken, and GPS location data were recorded.

Quantitative assessment

The Braun-Blanquet Relevé Method (Barbour et al., 1987) was utilized by field teams to collect data on species richness and vegetative cover. The Relevé Method involves an overall assessment of the wetland to determine the location that best represents the wetland plant community as a whole. This location then becomes the center of the sample plot. Minimum plot sample size is established based on an assessment of nested quadrats. For this study, the initial quadrat consisted of a 1-meter radius, circular plot. The sample size is then increased until the sample plot contains 90–95% of the dominant species present in the plant community, identified during the initial qualitative assessment phase.

Several parameters are recorded within each quadrat. The parameters include percent cover of each species present and the number of plant species within each quadrat. Percent cover estimates were visually estimated within cover classes defined by the Braun-Blanquet cover scale (Barbour et al., 1987).

Collection protocol

Ten wetland biologists working in 2-person field teams implemented the field data collection process. The teams sampled 13 pipeline projects in 15 states across 6 ecoregions, starting in August 2002 and ending in June of 2003. The study design targeted peak growing season for data collection within each of the ecoregions.

To ensure consistency in the field data collection, a 2-day training session was conducted for all biologists participating in field surveys. The first half of the training consisted of an in-office review of the data form specifically designed for this study, and the format and objectives of the data to be collected. Data management protocols were also established for both paper and electronic data. Electronic data would be downloaded each night to avoid the possibility of losing data due to equipment failure or damage. Training was also provided on how to select reference wetlands as the best representation of what was likely the pre-construction condition of the on ROW wetland.

The second half of the training was in the field to ensure consistent interpretations of the field data collection protocol and to provide an opportunity for on-site discussions pertaining to any topic that might be unclear. Field teams were also instructed to prepare field sketches of wetland systems, take additional photographs where appropriate, and record observations relating to wetland field conditions.

Following field surveys, field teams immediately photocopied field survey notes and secured originals in appropriately designated binders to ensure that no data was lost or misfiled. Copies of the field notes were then used to perform quality assurance\quality control (QA\QC) on photo logs and for data entry into the specifically designed Database.

Preliminary queries were run on the Database following data entry to ensure accurate data entry and that no null values were observed in query results. Preliminary Vegetation and Diversity Summary Reports were also printed and reviewed for accuracy following each field survey event.

Data analysis

After information on field data forms was entered into the Database, queries were written to test each wetland against the success criteria set by the FERC in the 1994 Procedures. Additionally, results from each of the queries were reviewed to identify trends that could be attributed to wetland restoration success or failure. Fields that were reviewed included pipeline construction year, current land use practices, climatic conditions, human disturbance, landscape position, soil type, and ecoregion. Reports for these analyses were designed into the Database.

Analyses relative to FERC success

The 1994 Procedures identified 3 success criteria that must all be met for the wetland to be considered successfully restored, as follows:

- The area must satisfy the requirements of the current Federal methodology for identifying and delineating wetlands (1994 Procedures, Section I.C.2.);

- The wetland must have at least 80 percent vegetative cover by native species (1994 Procedures, Section VI.E.3.); and
- The diversity of native species must be at least 50 percent of the diversity originally found in the wetland (1994 Procedures, Section VI.E.3.)

Total Vegetative Cover Criterion

The eighty percent (80%) vegetative cover criterion was determined by visual estimation of total vegetative cover for the portion of the wetland located on ROW. If the subject wetland had a vegetative cover of 80% or greater, the vegetative cover criterion was met. If the total vegetative cover was less than 80%, then the wetland failed to meet this success criterion.

Wetland Vegetation Criterion

The National List of Plant Species that occur in Wetlands (Reed and Porter, 1988) (hereafter National list) was used to determine which species are considered hydrophytes. The cover-class midpoints for all hydrophytes were summed and the relative cover of hydrophytes was calculated by expressing the sum of the hydrophytes as a percentage of the sum of the midpoints for all the species recorded in the sample plot. To exclude the contribution of non-native species from the calculation, all nonindigenous species, as identified by the United States Geological Survey Nonindigenous Aquatic Species database (USGS, 2003), were assigned a hydric class of "NA," excluding their midpoints from the calculation for relative cover of hydrophytes. If the relative cover of hydrophytes was 50 percent or greater, then this success criterion was met for jurisdictional wetlands.

Diversity Criterion

Diversity is a measurement of the number of species within a unit area (species richness) and the relative abundance or distribution (evenness) of those species. The FERC success criterion for diversity requires that the post-construction wetland have at least 50% of the diversity of the original wetland. For this study, the Shannon–Weiner Index, one of the simplest and most extensively used diversity indices in plant ecology, was used.

The formula for the Shannon–Weiner function is:

$$H' = (3.3219)\left[\log_{10} N - 1/N \sum (p_i \log_{10} p_i)\right]$$

where:
H' = Diversity index,
N = Sum of the cover class mean for all species,
p_i = Proportion of all individuals in the sample which belong to species i,
$\log_{10} p_i$ = the log to the base 10 of that proportion.

If the diversity of the on-ROW wetland is 50 percent or greater than the reference wetland, then the success criterion was met.

Trends analysis

Data collected during the field effort were reviewed for completeness and then entered into the Database. Reports were then generated and analyzed to identify trends in the data. Study objectives were to observe trends in the results and to identify relationships between those results and the 1994 Procedures. Queries were run in the Database to tally total number of passing and failing wetlands based on the 1994 Procedures. Summary reports were generated to display all fields of passing and failing wetlands.

Statistical analysis

Statistical methods were used to examine the influence of several factors on the success of wetland restoration. For these analyses the dependent variable was identified as "success" (1 = success, 0 = unsuccessful) and nine field variables were chosen to be independent factors. These nine independent factors were: ecoregion, evidence of construction debris, evidence of erosion, meets pre-construction grade, waterbar within 100 feet, evidence of human disturbance, wetland position in the landscape, soil texture, and evidence of top soil mixing.

A factorial design analysis of variance (ANOVA, F Statistic) with a randomized complete block design was used to test for significant independent variables. A Tukey HSD (Honestly Significantly Different) all-pairwise comparisons test was used to examine differences between groups where ANOVA models indicated a difference was present. Contingency tables and the Chi-square test (X^2 Statistic) were used to test for homogeneity of the proportions between groups (e.g., ecoregions) for each of the variables.

RESULTS AND DISCUSSION

This section provides a summary of results and a discussion of major trends observed through analysis of the data. The first part of this section provides an overall summary of the relative success or failure of the wetlands studied and general trends in the plant community composition and condition. Secondly, a summary of trends observed in physical factors that may have an effect on relative success or failure is provided. Finally, trends related to post-construction human disturbance and their suggested effects on restoration success are discussed.

General results and trends in post-construction plant communities

Project wetland restoration summary

Of the total 480 wetlands surveyed, 313 (65%) of wetlands passed the 1994 Procedures restoration success criteria and 167 (35%) failed. Table 1 provides a breakdown of total wetlands passing and failing the wetland

Table 1. Overall wetland restoration summary

Factor evaluated	Number	Percent of total
TOTAL WETLANDS MONITORED	480	100
Wetlands Passing Procedures Criteria[1]	313	65
Wetlands Failing Procedures Criteria[2]	167	35
Wetlands Failing More than One Criterion	44	9
Wetlands Failing Cover and Diversity	5	1
Wetlands Failing Cover and Wetland Vegetative Cover	35	7
Wetlands Failing Diversity and Wetland Vegetative Cover	0	0
Wetlands Failing All Three Criteria	4	< 1
Wetlands Failing only One Criterion	123	26
Wetlands Failing 80% Cover only	73	15
Wetlands Failing Diversity only	20	4
Wetlands Failing Wetland Vegetation Criterion Only	30	6
SUMMARY OF WETLAND FAILURES BY CRITERION[3]	–	–
Total Wetlands Failing 80% Cover Criterion	117	24
Total Wetlands Failing Diversity Criterion	29	6
Total Wetlands Failing l Wetland Vegetation Criterion	69	14

[1] Wetlands must pass all 3 criteria identified in the 1994 Procedures to be considered a passing wetland.
[2] Wetlands only needed to fail 1 criterion to be considered a failed wetland.
[3] The sum of "wetland failures by criterion" exceeds the total number of wetland failures because some wetlands failed 2 or more of the success criteria.

restoration criteria and a breakdown of wetland failures by criterion. Wetlands designated "passing" were required to meet all 3 of the restoration criteria. Wetlands identified as "failing" only needed to fail 1 of the 3 criteria (but may have failed more than 1 criterion). The most common single factor for failure was less than 80% vegetative cover by native species.

Of the total 480 wetlands surveyed, 411 (86%) were determined successfully restored as jurisdictional wetlands. Based on these results, application of the FERC's requirement to reestablish vegetative cover in the wetlands to 80% of the pre-construction conditions could be considered a more restrictive regulatory requirement than those required to simply restore the wetland to comply with the current federal definition.

Figure 3 illustrates the distribution of wetland failures by FERC criterion, total number of wetland failures per criterion, and the overlap of wetlands failing for more than 1 criterion. As indicated in both Table 1 and Fig. 4, failure to meet the 80% cover by native species criterion was the most common reason for wetland failure. One hundred and seventeen (117) wetlands failed to achieve 80% cover by native vegetation, this was 24%, or almost one fourth of the total wetlands surveyed.

The distribution of wetland success and failure for each ecoregion was assessed for all parameters evaluated in subsequent sections. As discussed above, pipeline projects were selected for survey based on their location within division-level ecoregions across the United States. The objective of collecting field data across several ecoregions was to determine if regional climatic conditions affect wetland restoration. Results of the study by ecoregion indicate differences in the relative success rate across the country. The average failure rate was 35% (range 11–68%). Failure rates were highest in the Temperate Steppe (68%) and Mediterranean (66%) ecoregions, and wetland failure rates were lowest in the Warm Continental (14%) and Hot Continental (11%) ecoregions (Fig. 4). Because the 1994 Procedures are applied consistently on projects regardless of geographic region, other variables, likely climatic and edaphic, are suspected of having a determining effect.

Climate diagrams of representative climate stations within each of the ecoregions surveyed are presented in Fig. 5. These provide a long-term average comparison of mean monthly precipitation and temperature for 12 months of the year for each ecoregion surveyed (Bailey, 1995). Three of the 6 ecoregions studied have wetland restoration success rates that were substantially higher than the average of 65% (86% Warm Continental, 89% Hot Continental, and 80% Subtropical, see Fig. 5). In each of these 3 ecoregions mean monthly precipitation exceeded mean monthly temperature. The wetland restoration success rate for the Prairie ecoregion was 70%. There is a corresponding difference in the climate diagram for the Prairie ecoregion (compared to the Warm and Hot Continental and Subtropical) – the mean monthly precipitation line is substantially closer to the mean monthly temperature line.

In both the Temperate Steppe and Mediterranean ecoregions, the mean monthly temperature is depicted as exceeding mean monthly precipitation lines for certain months during the year. These areas are shown in brown on the Temperate Steppe and Mediterranean climate diagrams and are identified as relative periods of drought. These diagrams indicate that climatic

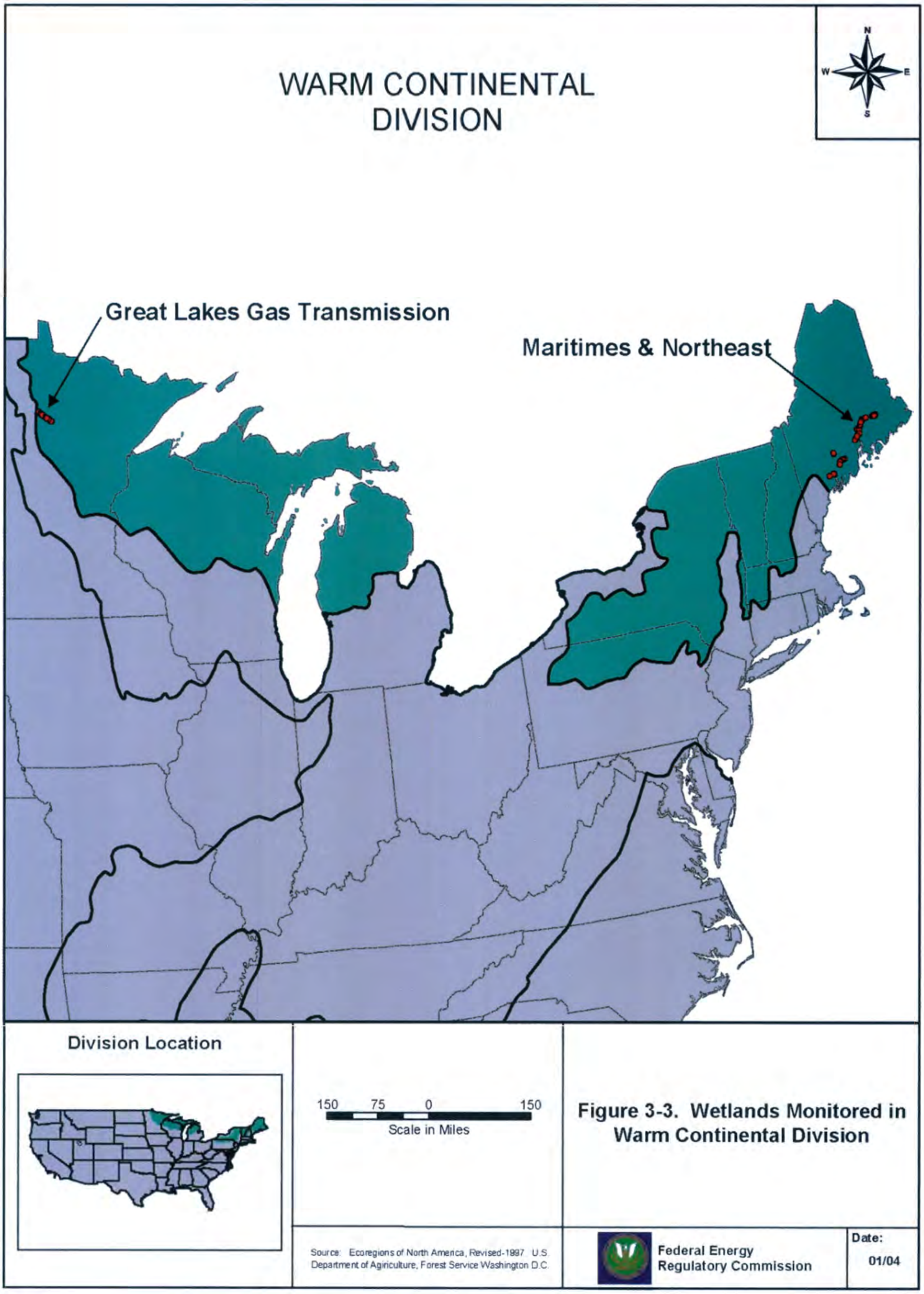

Fig. 3. Distribution of wetland failures by FERC criterion.

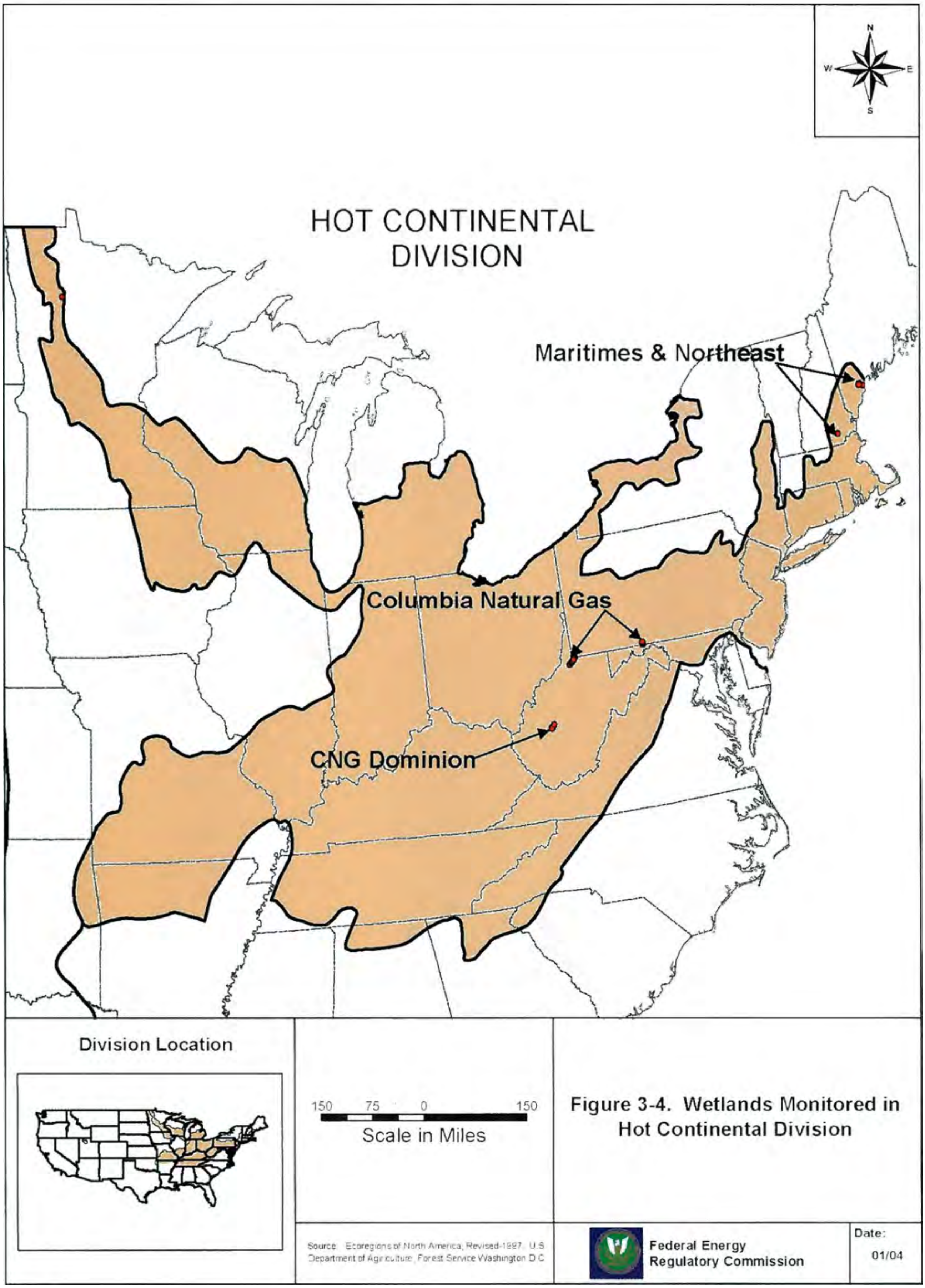

Fig. 4. Distribution of wetland failures by ecoregion.

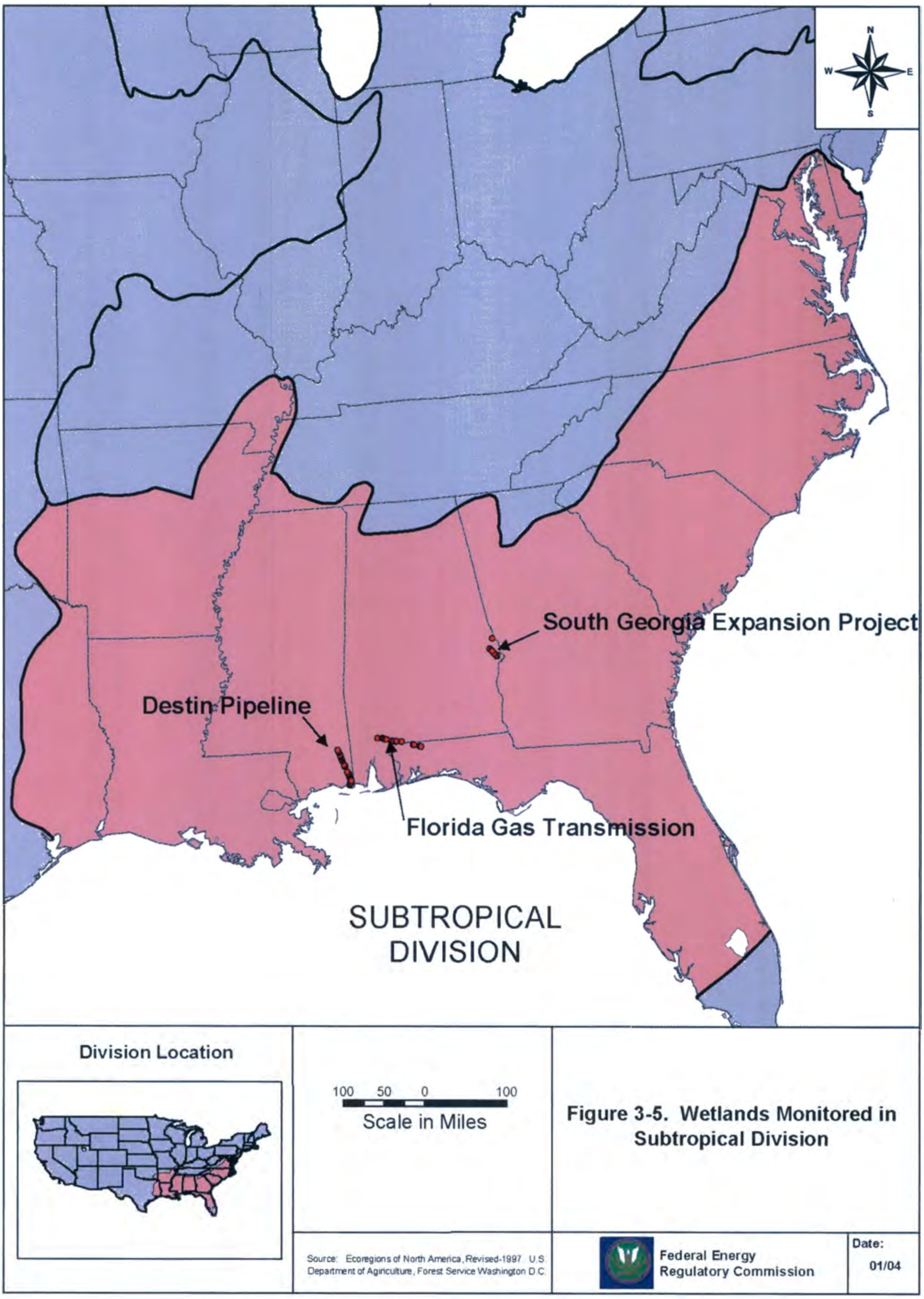

Fig. 5. Climate diagrams for study ecoregions.

conditions support periods of drought during parts of August, September, and October in the Temperate Steppe ecoregion, and during late May through September in the Mediterranean ecoregion. The establishment and persistence of hydrophytic vegetation is tied to the presence of moist hydrologic conditions. These data may provide an indication as to why both the Temperate Steppe and Mediterranean restoration failure rates (68% and 66% respectively) were substantially higher than the study average of 35%. Reference wetlands within these ecoregions exhibited identical wetland failure rates as those located on ROW, supporting the hypothesis that wetland failures were not construction related but more likely attributed to climatic conditions. In addition, wetland scientists noted evidence of drought conditions during field surveys for the Temperate Steppe ecoregions.

Because the climate diagrams provided in Fig. 5 represent "average" climatic conditions over a period of many years, additional research was performed in an effort to document "drought conditions" in these regions. Maps from the U.S. Drought Monitor were used for this study because they are based on a synthesis of multiple drought indices and represent a consensus of Federal and academic scientists (http://www.drought.unl.edu/dm/monitor). The U.S. Drought Monitor is a partnership consisting of the U.S. Department of Agriculture (Joint Agricultural Weather Facility and National Water and Climate Center), the National Weather Service's Climate Prediction Center, National Climatic Data Center, and the National Drought Mitigation Center at the University of Nebraska.

Figure 6 is the U.S. Drought Monitor Map for the week ending September 10, 2002, the same time period field surveys were performed in the Temperate Steppe ecoregion. This map shows severe, extreme, and exceptional drought conditions within the Temperate Steppe ecoregion at the time of survey. Table 5 defines the categories used in the classification system employed by the U.S. Drought Monitor.

A review of the historic maps from the U.S. Drought Monitor archives revealed abnormally dry conditions in the Temperate Steppe and portions of the Mediterranean ecoregions since 1999.

Other potential explanations for the high rate of failure of the wetlands in the Temperate and Mediterranean ecoregions are a high incidence of wetlands with clay soils and human-related wetland disturbances. These results are discussed in more detail below.

Wetland cover class conversion

A total of 480 wetlands, comprising 9 Cowardin wetland classes (Cowardin et al., 1979), were surveyed from among the 6 ecoregions studied (80 wetlands/ecoregion). The most common wetland class surveyed was palustrine emergent (PEM), with 279 wetlands (55.5%). The other commonly surveyed wetland types were palustrine forested (PFO) (91 wetlands; 18.1%) and palustrine scrub–shrub (PSS) (49 wetlands; 9.7%). Although the distribution of wetland classes was not in exact proportion to their abundance within each ecoregion, in general a fairly good representation of the wetland classes found commonly in each ecoregion was surveyed.

Construction of a pipeline ROW requires that vegetation be cleared. Furthermore, the conversion of the vegetation in ROW wetlands to early successional stages following construction is well documented (Santillo, 2000). Consistent with this, a comparison of the post-construction cover classes to their pre-construction types revealed a relatively large shift to early successional cover classes; over 78% of the ROW wetlands (394) were classified as PEM following construction while only 58% (279) were classified as PEM prior to construction. Comparing ROW wetlands to the pre-construction wetland classes, the number of wetlands in all wetland classes dominated by woody vegetation was reduced. Figure 7 shows a comparison of each Cowardin cover class pre- and post-construction.

Study results showed an overall increase in PEM wetlands and decrease in PFO and PSS wetlands following construction. These trends may be the result of the short period of time since implementation of the 1994 Procedures relative to the expected time frame for the re-establishment of arboreal vegetation. However, we expect this trend to persist over portions of the ROW because vegetation maintenance is commonly used to facilitate monitoring required by the U.S. Department of Transportation to ensure pipeline integrity. The 1994 Procedures (Section VI.E.1) allow for vegetation maintenace within the ROW to facilitate aerial corrosion and leak surveys. More specifically, the Procedures allow for maintenance of vegetation in a herbaceous state within a 10-foot-wide corridor (centered over the pipeline) and the removal or selective cutting of trees greater than 15 feet in height from within 15 feet of the pipeline, or a 30-foot corridor centered over the pipeline.

This trend is considered inconclusive due to the relatively short timeframe since construction for many of the pipelines surveyed and, therefore, insufficient time for plant succession to occur. Overall, conversions of Cowardin classes were consistent with what was expected following construction based on climatic conditions within ecoregions, and time since construction.

Influence of physical factors on restoration success

A number of key physical factors were identified by the Team for testing relative to their effect on wetland revegetation success or failure. Although data on numerous physical parameters were collected, the factors analyzed in this section were those considered by the Team to have the greatest likelihood of affecting wetland revegetation success.

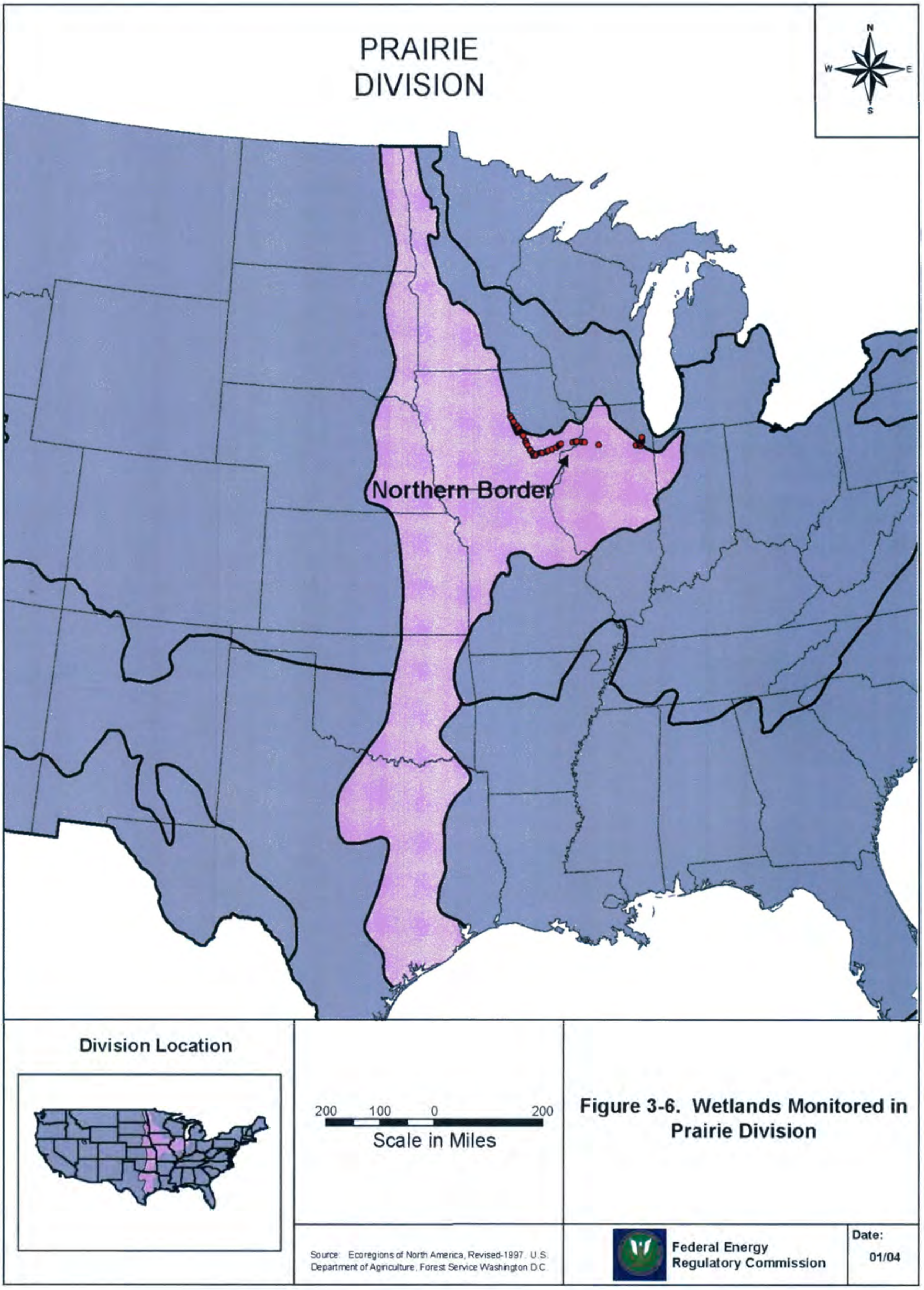

Fig. 6. U.S. drought monitor map for week ending, September 10, 2002.

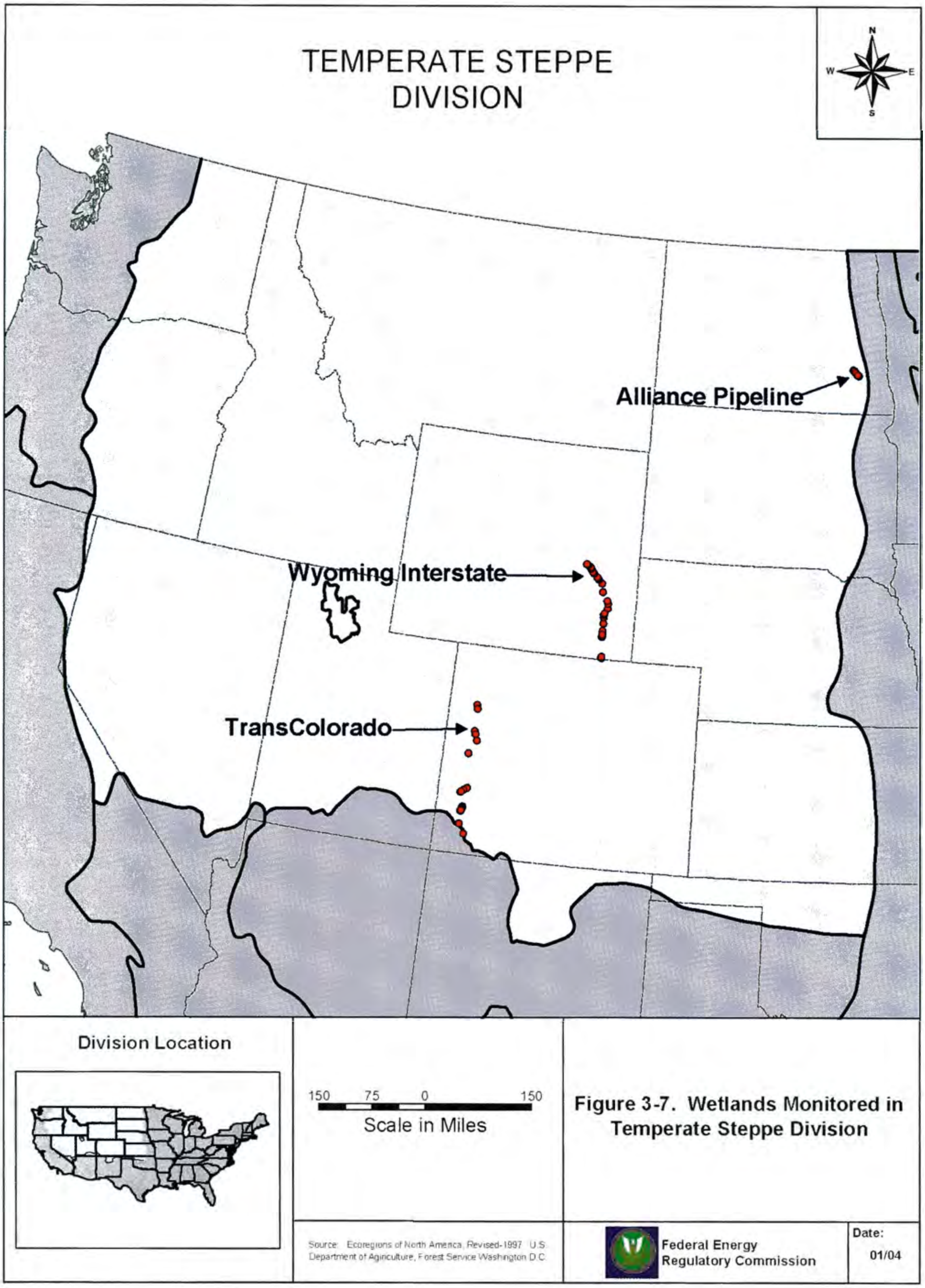

Fig. 7. Changes in Cowardin Classification from pre- to post-construction conditions.

Table 2. Summary of wetland restoration relative to position of wetland in landscape

Landscape position	Overall distribution		Passing wetlands		Failing wetlands		Percent of all failures
	Number	Percent	Number	Percent	Number	Percent	
Bottom	228	60	197	68	91	32	54
Vegetated Swale	100	21	64	64	36	36	22
Sidehill	14	3	10	71	4	29	2
Riparian	66	14	39	59	27	41	16
Other	12	3	3	25	9	75	5
Total	480	100	313	65	167	35	100

Table 3. Wetland restoration success related to soil type

Soil texture class	Overall		Passing wetlands		Failing wetlands		Percent of all failures
	Number	Percent	Number	Percent	Number	Percent	
Rock	2	0	1	50	1	50	1
Organic	26	5	20	77	6	23	4
Sands	151	31	113	75	38	25	23
Silts	21	4	15	71	6	29	4
Clays	183	38	95	52	88	48	53
Loams	86	18	64	74	22	26	13
Inundated	11	2	5	45	6	55	4
Total	480	100	313	65	167	35	100

Wetland landscape position

Five wetland landscape positions were evaluated to determine if restoration success varied among these types following pipeline construction. Table 2 presents results for wetland landscape position and lists the percent passing and failing wetlands in each landscape position. Sixty percent (228) of all wetlands surveyed were located in the bottom landscape position. Sixty-eight percent (197 wetlands) of wetlands located in the bottom landscape position passed the FERC criteria.

Vegetated swales typically are relatively narrow and shallow vegetated wetlands. Sidehill wetlands are found mid-slope or along a grade and are often supported by side hill seeps or surface hydrology. Riparian wetlands are those found along moving water bodies (river, streams, brooks) and usually are hydrologically connected to the adjacent water body. The wetlands in the "other" category were identified as vernal pools.

The average failure rate for wetlands, regardless of landscape position was 35%, and the range for landscape position was 29–75%. However, if the relatively small number of vernal pools (12) are omitted, then the percent of wetlands failing among the various landscape positions fell within a relatively narrow range of 29 to 41%. Accordingly, there were no major patterns in the success of wetland restoration relative to landscape location, although the low success rates for vernal pools may warrant consideration on future projects.

Soil type

Soils were sampled within on-ROW and reference wetlands using the United States Department of Agriculture's (USDA's) soil textural classification system grouped into 6 smaller classes based on dominant soil textural class. The classes used were rock, organic, sand, silt, clay, and loam. These groupings resulted in larger sample sizes for each soil type.

Table 3 presents the relative distribution of soil types found in the wetlands surveyed, along with the number and percent of passing and failing wetlands for each category of soils. Wetlands with clay dominated soils were the most common (38%) wetland type surveyed; sand dominated soils were the second most common (31%); and wetlands with loam-dominated soils were the third most common (18%).

As indicated in Table 3, the percent of wetlands that failed was greatest in clay soils from among the five non-rock soil types; 48% of wetlands with clay soils were not successfully restored. Eighty-four (84%) of these wetland failures were found in wetlands located in the Temperate Steppe ecoregion, which was experiencing drought conditions at the time of survey. Clay soils can be especially challenging during construction because of their capacity to hold water. Fine colloidal clays have approximately 10,000 times as much surface area as the same weight of medium-sized sand (Brady, 1984). Clay soil particles are also platy in shape causing them to be plastic when wet and extremely hard to cemented when dry, a condition that might be expected under drought conditions. These soil characteristics can also pose significant challenges for wetland restoration. In addition, fine-grained soils, such as clays, support relatively low rates of germination, establishment, and survival of seeds (Leck et al., 1989). Further evidence of this was observed by Santillo (2000) who found that vegetation recovery was lower on portions of pipeline ROWs where topsoil-subsoil mixing resulted in clay subsoil at the surface. The failure rates for the other four non-rock soil types (organic, sand, silt, and loam) fell within a narrow range of 23 to 29%.

Wetland hydrology

Wetland hydrology was evaluated to determine if there was any relationship between saturation and depth of surface water and wetland restoration success and failure. In general, reestablishment of natural surface hydrologic conditions is regarded as a major key to wetland restoration (Mitch and Gosslink, 1993), and the amount of water present has been documented to be a driving factor that determines what plant species become established (Van der Valk, 1981). Table 4 presents the depths of surface water observed in wetlands surveyed.

Sixty (60%) of wetlands surveyed were observed with <1 inch of surface water at the time of survey; this hydrologic class encompassed wetlands that had no standing water at the time of the survey. In addition, 33% had between 1 and 6 inches, 5% had between 6 and 12 inches, and 3% had >12 inches of standing water at the time of survey. For wetlands with between 0 and 12 inches of water depth, the success rate was between 60 and 79%. In general, this is consistent with other studies that have documented relatively rapid recovery of flooded emergent wetlands following disturbance (Farnworth, 1979; Odegard, 1978).

The hydrologic class with the highest rate of failure was >12 inches of water; 83% of wetlands with >12 inches of water failed to meet the FERC criteria. The relatively high failure rate for wetlands in >12 inches of water was primarily related to not meeting the 80% vegetative cover criterion. Before categorizing these wetlands as failures, however, these wetlands should be compared to pre-construction conditions, to establish if an area of open water (and lacking vegetative cover) was the normal condition that existed prior to construction. Such wetlands may not in fact be "failures" if they had areas of open water prior to construction and did not have 80% cover in their pre-construction state.

Influence of human disturbance on restoration success

Wetlands affected by human disturbance

Six categories of human disturbance were identified as potentially affecting wetland restoration success, including: ATV use, paving or fill activities, agricultural activities, residential development or lawns, and other. Other types of wetland disturbance reported included: pond construction for recreational use, trampling by cattle, and various drainage-related construction (Table 5).

Nearly half (47%) of all wetlands surveyed contained some evidence of human disturbance. Of the wetlands affected by human disturbance, 51% were successfully restored and 49% failed to meet the FERC wetland restoration criteria. However, two-thirds (66%) of all failed wetlands overall had evidence of human disturbance, thus suggesting this to be a contributing factor to failure.

Of the wetlands with evidence of human disturbance and not successfully restored, 75% failed the cover criterion, 49% failed the wetland vegetation criterion, and 9% failed the diversity criterion. Figure 8

Table 4. Wetland restoration related to depth of surface water

Surface water depth	Overall distribution		Passing wetlands		Failing wetlands		Percent of all failures
	Number	Percent	Number	Percent	Number	Percent	
<1″	287	60	172	60	115	40	69
1″–6″	157	33	124	79	33	21	20
6″–12″	24	5	15	63	9	38	5
>12″	12	3	2	17	10	83	6
Total	480	100	313	65	167	35	100

Table 5. Wetlands affected by human disturbance

Type of human disturbance	Total wetlands affected	Percent of wetlands surveyed	Passing wetlands		Failing wetlands		Percent of all failures
			Number	Percent	Number	Percent	
Farming	130	27	40	31	90	69	54
ATV	78	16	65	83	13	17	8
Other	18	4	10	56	8	44	5
Lawn	3	1	2	67	1	33	1
Paved/Fill	1	0	1	100	0	0	0
Total	225	47	115	51	110	49	66

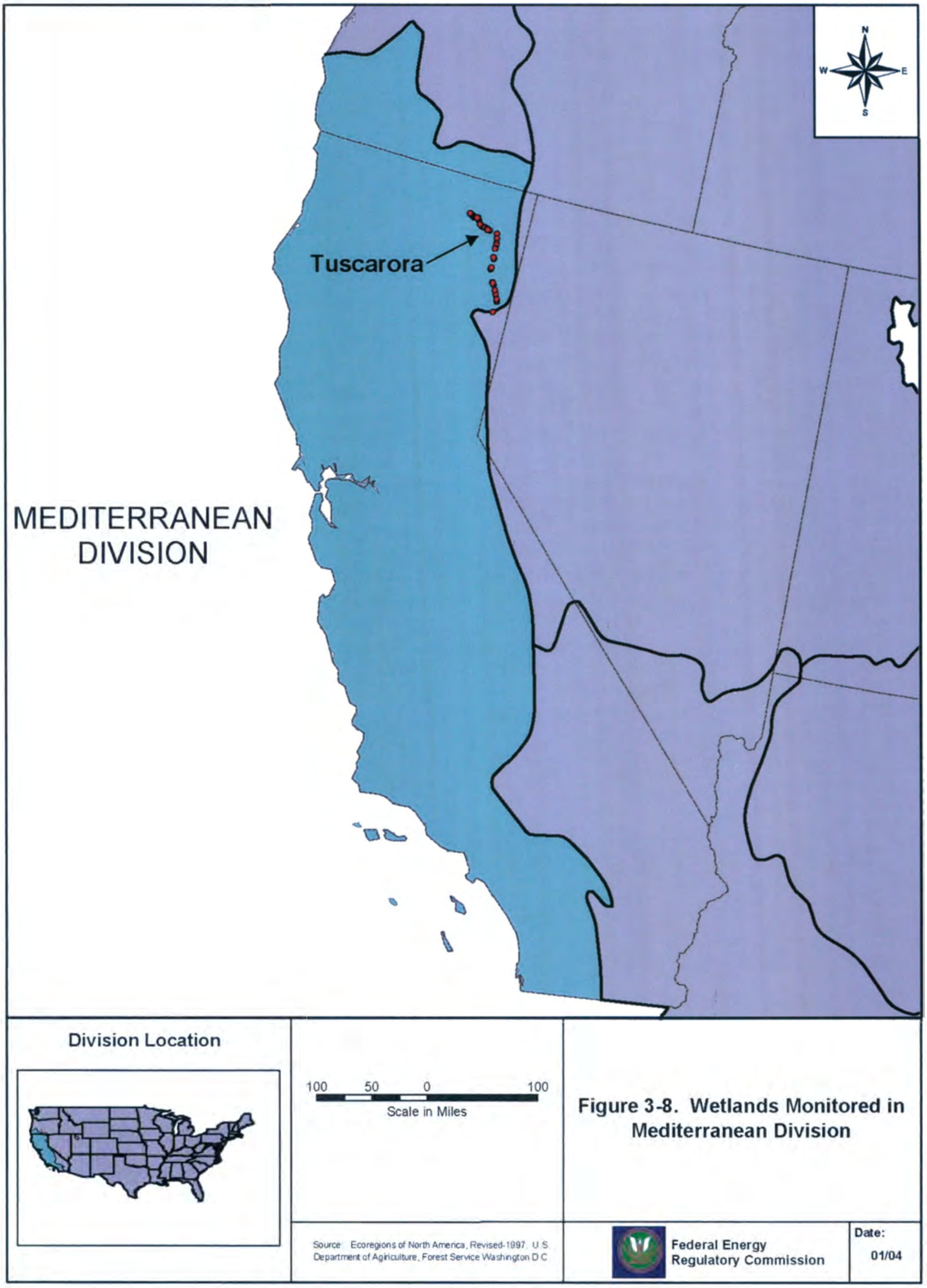

Fig. 8. Breakdown of types of human disturbance observed in wetlands.

shows the distribution of types of human disturbance observed within wetlands during field surveys. Seventy-two percent (72%) of failed wetlands with human disturbance were located in the Temperate Steppe Ecoregion, and 97% of these wetlands were reported to have farming-related human disturbance.

A relatively high percentage (47%) of all wetlands surveyed were disturbed by human activity. The obvious explanation is that most natural gas pipelines are constructed within easements that allow property owners continued use of their land, and a cleared ROW invites various uses by landowners and the general public.

The large proportion (58% or 130 wetlands) of farmed wetlands can be explained because farmed land and subsurface pipelines generally are considered compatible land uses. The existence of the subsurface pipeline does not inhibit continued cultivation of the land and the existence of crops does not affect pipeline operations.

The study revealed that 35% (78 of 225) of wetlands affected by human disturbance, were disturbed by ATVs (Fig. 9); 83% of these wetlands damaged by ATVs passed, and only 17% failed, the restoration criteria. Smaller wetlands had a higher failure rate than larger wetlands, potentially because the ATV trails covered a larger percentage of the area of the entire wetland. The portions of wetlands that were affected (the ATV trails) often were devoid of vegetation and had compacted soils, or were deeply rutted. ATV trails that ran parallel to the direction of slope (straight down hill) and that damaged permanent slope breakers (making them ineffective) generally cause the greatest damage. These ATV trails can become problematic sources of sedimentation in down-gradient and adjacent water resources, and can modify normal drainage patterns.

There was ample evidence observed in the field that pipeline companies have gone to great lengths to deter ATV use on the ROWs, including: gates and fencing; signs with warnings of severe penalties; and placement of large boulders, logs, or trees across the trails. However, signs were often vandalized, boulders and logs were moved, and new trails were created in other locations to allow access by the ATVs.

Waterbar placement

The 1994 Procedures (Section VI.D.2) required the placement of permanent slope breakers or waterbars at the base of slopes near the boundary between wetlands and adjacent uplands. Waterbars are permanent slope breakers, usually earthen berms, constructed perpendicular to the direction of slope. The purpose of waterbars is to slow the accumulation and velocity of surface water runoff (with sediments) and to divert water off the ROW before it causes soil erosion. Table 6 presents wetland restoration results for wetlands observed with associated waterbars.

For the purpose of this study, it was assumed that wetlands surveyed that did not have waterbars did not require waterbars due to flat topographic conditions. Waterbar placement was evaluated in this study because of the potential for waterbars to affect the amount of surface water entering a wetland, and because the absence of waterbars can lead to the accumulation of sediment within wetlands. Where wetlands are dependent on upgradient surface water hydrology, a waterbar placed at the base of a slope could conceivably divert enough surface water away from the wetland so that it begins to transition into an upland community. However, the results did not support this concept.

Waterbars were observed adjacent to 35% of all wetlands surveyed. Of the wetlands observed with upgradient waterbars, 74% (126) were successfully restored and passed the criteria included in the 1994 Procedures.

Pipeline construction dates

Pipeline construction dates were evaluated to determine if there was a relationship between wetland restoration success and the amount of time the wetlands had to recover following construction.

Table 7 shows the distribution of pipeline construction dates for the pipeline projects included in the study, along with the percent of passing and failing wetlands. The highest wetland restoration success rate (88%) was observed in the oldest pipeline construction year (1995). The lowest wetland success rate (39%) was observed in the second oldest pipeline construction year (1996). The second highest success rate (80%) was observed in the youngest (2001).

The results of this study do not present a clear correlation between relative success rate and time since construction. Although the best success rate (88%) was achieved in the oldest projects surveyed (1995), the lowest rate (39%) was achieved only 1 year later (1996). The remaining results show similar variability from year to year, thus indicating that other factors aside from time since construction were having an overriding effect on wetland restoration success and failure.

Restoration grade

Post-construction restored grade was evaluated to determine if there was a correlation between wetland restoration success and the reestablishment of pre-construction grades within wetlands. Qualitative judgments were made by field crews to determine if grading within the wetland was reestablished to pre-construction conditions. This observation was then recorded as a "yes" or "no" on the dataform. Typical field observations that indicate grades were not reestablished to pre-construction conditions include: obvious deviations from off-ROW topographic conditions (i.e., excess fill material higher than surrounding

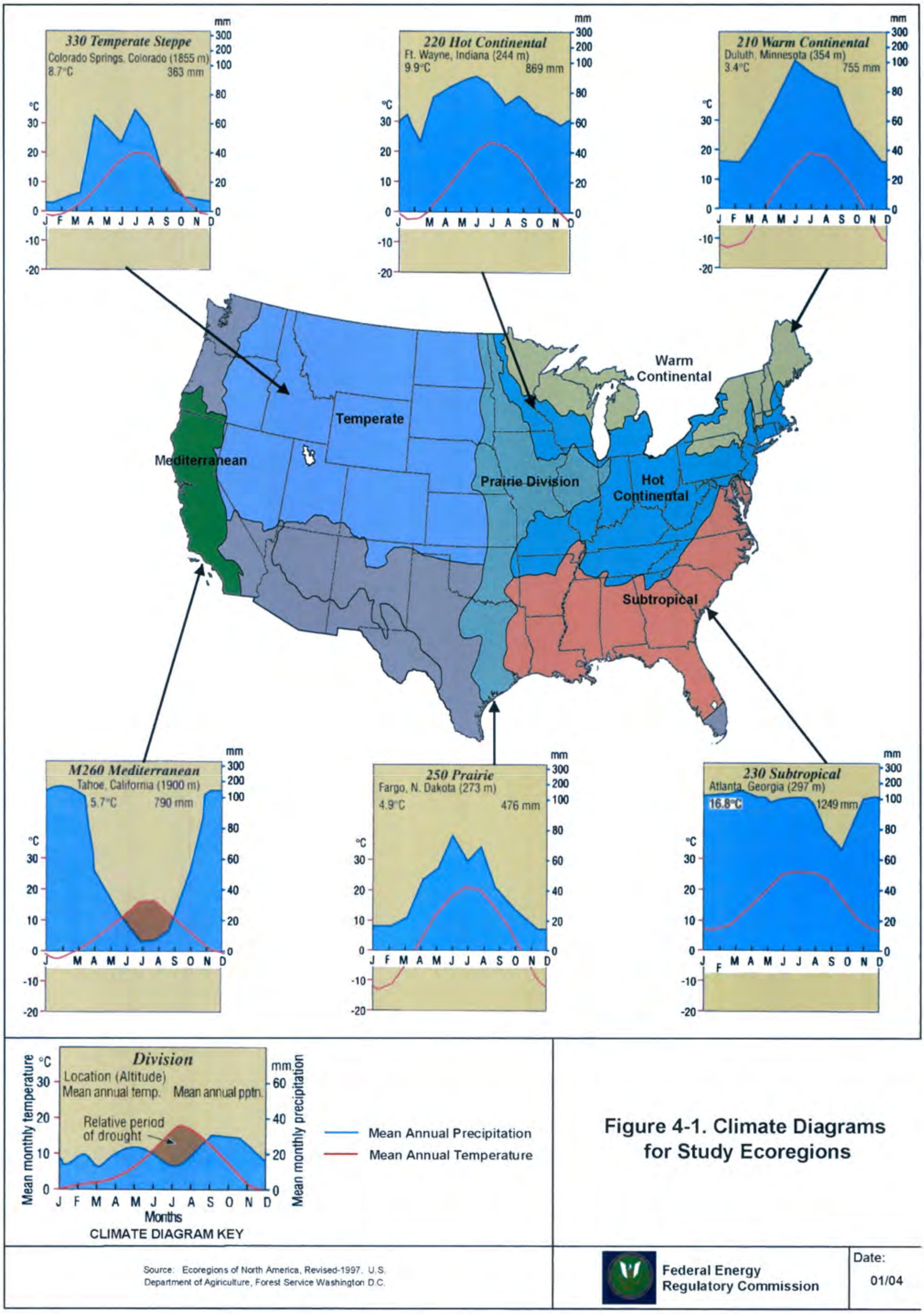

Fig. 9. Photograph of wetland failing cover criterion due to impacts from ATVs.

Table 6. Wetland restoration relative to existence or placement of waterbars

Waterbar position	Overall distribution		Passing wetlands		Failing wetlands		Percent of all failures
	Number	Percent	Number	Percent	Number	Percent	
No waterbar	311	65	187	60	124	40	74
Upgradient	146	30	108	74	38	26	23
Downgradient	1	0	0	0	1	100	1
Both	22	5	18	82	4	18	2
Total	480	100	313	65	167	35	100

Table 7. Wetland restoration summary for pipeline construction years

Pipeline construction year	Years since wetland disturbance	Overall distribution		Passing		Failing		Percent of all failures
		Number	Percent	Number	Percent	Number	Percent	
1995	7	25	5	22	88	3	12	2
1996	6	90	19	35	39	55	61	33
1998	4	174	36	132	76	42	24	25
1999	3	151	31	96	64	55	36	33
2000	2	10	2	4	40	6	60	4
2001	1	30	6	24	80	6	20	4
Total	–	480	100	313	65	167	35	100

Table 8. Multiple factor analysis of variance effects test on success

Source	Df	SS	MS	*F*	*P*
*Ecoregion	5	12.0580	2.4116		
Construction debris	1	0.0425	0.0425	0.25	0.6159
Evidence of erosion	1	0.0006	0.0006	0.00	0.9518
*Meets pre-construction grade	1	1.0100	1.0100	5.99	0.0148
Water bar within 100 feet	1	0.0766	0.0766	0.45	0.5007
*Evidence of human disturbance	1	1.6755	1.6754	9.93	0.0017
Wetland position in landscape	4	0.6179	0.1544	0.92	0.4545
Soil texture	13	3.0706	0.2362	1.40	0.1551
Top soil mix	1	0.0007	0.0007	0.00	0.9505
Error	451	46.0699	0.1686		
Total	479	Grand mean 1.47		CV 27.88	

Notes:
The whole model was significant ($F = 6.95$, $P < 0.0001$).
*Indicates significant factor.
Similar results were obtained using grouped soil texture categories (e.g., sands, clays).

topography or large depressions atypical of surrounding conditions). Of the wetlands that were restored to pre-construction grades, 67% were successful, whereas in wetlands where pre-construction grades were not restored, only 35% of the wetlands were successful.

Statistical analysis

Based on some of the observations made during the trends analysis, statistical tests were applied to examine the influence of nine independent variables on the success of wetland restoration. Three factors were found to have a significant influence on whether or not a wetland would be successfully restored (Table 8). These 3 factors are discussed below.

The ecoregion from which the wetland was sampled had a significant influence on the success of the restored wetlands (Table 8). Further testing indicated that the success rate of the wetlands in the Hot Continental, Warm Continental, Subtropical, and Prairie ecoregions were not statistically different from each other, but the rates were significantly different than those of the Temperate Steppe and Mediterranean ecoregions. The success rate of the Temperate Steppe and Mediterranean ecoregions were similar.

The "eastern" (i.e., Hot Continental, Warm Continental, Subtropical, and Prairie) ecoregions had an 82% success rate whereas those in the extreme West (i.e., Temperate Steppe and Mediterranean) had a 33% success rate.

Whether or not a wetland exhibited evidence of human disturbance was also a significant factor in determining the success of a restored wetland. Wetlands

Table 9. Statistically significant factors in determining successful restoration

	% Successful					
	Hot continental	Warm continental	Subtropical	Prairie	Mediterranean	Temperate steppe
Ecoregion	86	86	80	70	34	32
	Yes			No		
Evidence of human disturbance	37			63		
Meets pre-construction grade	67			35		

Table 10. Significant explanatory factors between eastern and western grouped ecoregions

Ecoregion group (wetland restoration success rate)	% Wetlands with evidence of human disturbance	% of Wetlands restored to pre-construction grade
East (83%)	34	97
West (17%)	72	92

Note: East group is comprised of the Hot Continental, Warm Continental, Subtropical, and Prairie ecoregions and the west group is comprised of the Temperate Steppe and Mediterranean ecoregions.

with evidence of human disturbance were associated with higher failure rates. Of the wetlands that exhibited evidence of human disturbance only 37% were successful, whereas if this evidence was absent 67% of the wetlands were successful (Table 9). In addition, in the more successful eastern ecoregions only 34% of the wetlands exhibited evidence of human disturbance when compared to the 72% for the western ecoregions (Table 10).

Whether or not a wetland was restored to pre-construction grade was the third factor found to be a significant in determining the success of a restored wetland. Wetlands not restored to pre-construction grade were associated with failure. Of the wetlands that were restored to pre-construction grade 67% were successful, whereas if pre-construction grade was not restored 35% of the wetlands were successful (Table 9).

CONCLUSIONS AND RECOMMENDATIONS

The FERC's 1994 Procedures were designed to minimize impacts to wetlands crossed by construction of natural gas pipelines and have been applied during pipeline construction since 1994. This study was designed to evaluate the effectiveness of the 1994 Procedures by analyzing the success and failure of wetland restoration following pipeline construction. A variety of factors that could potentially influence success were examined and presented in previous sections of this report. The following is a summary of substantive conclusions and notable trends:

- Existing wetland monitoring reports were largely unavailable from pipeline companies contacted. Based on post-construction wetland monitoring reports that were received, it is evident that the pipeline industry does not have a consistent approach to performing post-construction wetland monitoring. The FERC's revised 2003 Procedures (VI.D.3.) now require that a report be filed with the Secretary identifying the status of the wetland revegetation efforts at the end of 3 years following construction. This requirement is anticipated to improve the status of post-construction wetlands monitoring for pipeline projects;
- Based on detailed quantitative field studies, approximately two-thirds of all wetlands studied nationwide achieved all 3 wetland restoration success criteria identified in the 1994 Procedures. Most wetlands that failed the FERC success criteria failed because of insufficient vegetative cover;
- The study revealed strong differences in overall success by ecoregion. Eastern and midwestern wetlands have significantly higher success rates than western ecoregions. Regional climates and weather conditions reveal noticeable trends in relative wetland restoration success and failure;
- The presence of human disturbance in wetlands was associated with higher failure rates, likely due to its influences on the percent vegetative cover criterion. The most common human disturbance category was farming, which includes cattle grazing, and could be a contributing factor to the lower success rate for wetlands occurring in the western ecoregions;
- Wetlands that achieved pre-construction grades (i.e., grading of the wetland was reestablished to pre-construction conditions) were significantly more successful than wetlands that did not meet pre-construction grades;
- Soil conditions appear to have some influence on wetland revegetation success, with wetlands underlain by clay-dominated soils having a greater failure rate than wetlands dominated by other soil types. Although this was a noticeable trend, soil texture

was not a significant factor based on the statistical analysis; and

- The data showed a strong trend of conversion of forested and scrub–shrub wetlands to emergent wetlands. This observation may be the result of the short period of time since implementation of the 1994 Procedures relative to the expected time frame for the reestablishment of arboreal vegetation. Therefore, this trend is considered inconclusive. In addition, we expect this trend to persist over portions of the ROW because ROW vegetation maintenance (removal of woody vegetation over the pipeline) commonly is used to facilitate monitoring required by the U.S. Department of Transportation to ensure pipeline integrity.

Recommendations

The following is a summary of recommendations resulting from this study:

- Methods used to monitor wetland restoration success should be standardized to ensure that wetland restoration can be evaluated consistently between projects and geographic regions over time. The wetland monitoring data form used for this study could be used as a template for future wetlands monitoring, but should be revised to reflect the changes incorporated into FERC's 2003 Procedures, if appropriate;
- Wetlands in the arid western ecoregions have a much higher rate of failure than wetlands in more humid regions of the country. This stark contrast warrants consideration of a modified version of the Procedures for the western regions that takes into consideration climate differences and local successional processes. Duration of monitoring and success criteria may need to be modified for these regions (i.e., longer monitoring periods, lower cover and diversity requirements, etc.);
- Evidence of human disturbance was associated with lower success rates regardless of ecoregion, and evidence of human disturbance was more prevalent for the western ecoregions than the eastern ecoregions. Post-construction monitoring to evaluate the effects of human disturbance on wetland restoration should be encouraged so that remedial measures can be developed; and
- Although only 23 of the 480 wetlands were not restored to pre-construction grades, this factor had a substantive effect in determining success. Therefore, current procedures that enforce the restoration of pre-construction grades should continue to be developed.

REFERENCES

Bailey, Robert G. 1995. Description of the Ecoregions of the United States. 2nd ed. Rev. and expanded (1st ed. 1980). Misc. Publ. No. 1391 (rev.), Washington, DC: USDA Forest Service. 108 pp. with separate map at 1:7,500,000.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology, second Edition. Benjamin/Cummings Publishing Co. Menlo Park, CA. 634 pages.

Brady, N.C. 1984. The Nature and Properties of Soils. Macmillan Publishing Company. New York, New York.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish & Wildlife Service. FWS/OBS-79/31. 103 pp.

Farnworth, E.G. 1979. Natural revegetation of tidal freshwater marsh disturbed by natural gas pipeline construction in Savannah, Georgia. Pages 42-1 to 42-29 in R.E. Tillman (ed.). Proc. 2nd Symp. on the Environmental Concerns in Rights-of-Way Management. Univ. of Michigan, Ann Arbor.

Leck, M.A., V.T. Parker, and R.L. Simpson. 1989. Ecology of Soil Seed Banks. Academic Press, Inc. San Diego, CA. 462 pp.

Mitch, W.J. and J.G. Gosslink. 1993. Wetlands. Van Nostrand Reinholt Company, Inc. New York, New York. 539 pp.

Odegard, G.J. 1978. Revegetation of two wetlands following pipeline construction in southern Maryland. 144th Annual Meeting of the American Association for the Advancement of Science. Washington, DC.

Reed, Jr., Porter B. 1988. National List of Plant Species That Occur in Wetlands: National Summary. U.S. Fish & Wildlife Service. Biol. Rep., 88(24): 244.

Santillo, D.J. 2000. The effects of construction of a new pipeline right-of-way on wetland birds and vegetation in northern New York State. Ph.D. Thesis. SUNY College of Environmental Science and Forestry. Syracuse, NY.

Soil Survey Staff. 1990. Keys to Soil Taxonomy, fourth edition. SMSS technical monograph no. 6. Blacksburg, VA.

U.S. Army Corps of Engineers. 1987. US Army Corps of Engineers Wetland Delineation Manual, Technical Report Y-87-1. Environmental Laboratory Department of the Army Waterways Experiment Station. Vicksburg, MS. 100 pp.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1996. Field Indicators of Hydric Soils in the United States. G.W. Hurt, Whited, P.M., and Pringle, R.F. (eds.). USDA, NRCS, Fort. Worth, TX.

U.S. Geological Survey. 2003. Nonindigenous Aquatic Species. Website: http://nas.er.usgs.gov (accessed July 30, 2003).

Van der Valk, A.G. 1981. Succession in wetlands: a Gleasonian approach. Ecology, 62(3): 688–696.

Walter, H., E. Harnickell, and D. Mueller-Dombois. 1975. Climate Diagram Maps of the Individual Continents and the Ecological Climate Regions of the Earth. Berlin: Springer-Verlag. 36 pp. with 9 maps.

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Part IX
Soils

A Horizontal Directional Drilling Best Management Practices Manual

Carl E. Tammi, Andrea M. Desilets, Eric R. Skonberg, Vipul Srivastava, and James M. Evans

Horizontal directional drilling (HDD) has emerged as an innovative technology for installing natural gas transmission lines, below-ground electric transmission lines and other utility lines under wetlands, waterways, and institutional features to minimize environmental impacts within rights-of-way. As HDD increases in usage as a less environmentally-damaging alternative to traditional open-trench excavations, the need for a manual outlining the applications, limitations and potential environmental implications of HDD, along with construction and environmental best management practices is evident. The Best Management Practices (BMP) Manual has been designed as a comprehensive decision-making tool which covers many facets of HDD planning, engineering, siting, construction and environmental protection and mitigation, particularly the management of drilling muds, contingency planning and BMPs. The Manual focuses largely on protocols for the prevention and management of inadvertent drill mud returns in ecologically-sensitive areas such as swamps, marshes, rivers and streams. The protocols provided in the Manual are intended to minimize environmental impacts from installation within rights-of-way. The BMP Manual has been prepared in a menu format with an emphasis on the ability for the user to quickly access sections that are most applicable to the user. By incorporating graphics, details and schematics and minimizing text, field inspectors and environmental planners alike should find the Manual suitable for reference as a guide. While universal in its applicability, the Manual's emphasis is for use in HDD operations for the natural gas pipeline industry. The Manual represents the culmination of five years of research funded by the Gas Research Institute (GRI; now, the Gas Technology Institute).

Keywords: HDD, best management practices, wetlands, bentonite, drilling fluids, inadvertent returns

INTRODUCTION

Horizontal directional drilling (HDD) has emerged as an innovative technology for installing natural gas transmission lines, below-ground electric transmission lines and other utility lines under wetlands, waterways, and institutional features to minimize environmental impacts within rights-of-way. As HDD increases in usage as a less environmentally-damaging alternative to traditional open-trench excavations, the need for a manual outlining the applications, limitations and potential environmental implications of HDD, along with construction and environmental best management practices is evident. A Best Management Practices (BMP) Manual has been designed as a comprehensive decision-making tool which covers many facets of HDD planning, engineering, siting, construction and environmental protection and mitigation, particularly the management of drilling muds, contingency planning and BMPs. While the primary objective of the Manual is to inform the audience of potential HDD environmental impacts and of the steps to take for prevention, mitigation and cleanup of such impacts, the Manual also provides a regulatory, technical and engineering framework for HDD. The Manual provides technical guidance on predicting

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and managing inadvertent drill mud returns during HDD operations and provides protocols along with schematic details for the management of returns.

Purpose

The purpose of the Manual is to assist the pipeline community in the decision-making process on a project-by-project basis for planning, permitting and staging of HDD operations. Although comprehensive in nature, this document focuses largely on methods to effectively deal with inadvertent drill mud returns. The Manual is also intended to reduce uncertainties for planners, regulators and field crews and to enhance coordination between engineers/planners and field construction teams. The BMP Manual was prepared in a format for use by field and office personnel alike, in a menu format as a guidance document that facilitates quick review. This is not merely intended as a technical primer on HDD. By incorporating graphics, details and schematics and minimizing text, field inspectors and environmental planners alike should find the Manual suitable for reference as a guide.

Audience

The Manual provides useful planning and procedural information to:

- Individuals who plan and seek permits for HDD operations (Natural Gas Transmission Line (NGTL) Environmental Managers);
- Contractors, field oversight personnel and others who are responsible for HDD construction operations; and
- Local, state and federal environmental officials, planners and regulators who will be permitting HDD operations (as a guidance tool).

REGULATORY REQUIREMENTS AND GUIDELINES

There are eight land- or water-use related U.S. federal regulatory programs which address horizontal directional drilling operations in a guideline or regulatory context. These programs do not regulate HDD directly per se, but the resources that may be crossed using HDD. These programs are: the Federal Energy Regulatory Commission Guidelines, the National Environmental Policy Act, The Clean Water Act, the Rivers and Harbors Act of 1899, the National Historic Preservation Act, the Endangered Species Act, the Coastal Zone Management Act and the Wild and Scenic River Act. These regulatory programs each have their own charter and specific jurisdiction.

There are five Canadian Federal regulatory programs that are relevant to horizontal directional drilling operations. These programs are: the Canadian Environmental Assessment Act, the National Energy Board Act, the Navigable Waters Protection Act, the Fisheries Act and the Indian Oil and Gas Act.

HDD TECHNOLOGY

Horizontal Directional Drilling (HDD) is a trenchless construction technique where a steerable pilot hole is drilled along a predetermined alignment and profile under and clear of an obstacle. The pilot hole may be enlarged through a sequence of reaming passes and the pipeline is pulled into the drilled hole.

HDD is different from pipe jacking and tunneling; it is surface launched without pits. It is similar to other trenchless techniques in that no excavation is required along the drill alignment and construction is generally limited to either side of the obstacle. The HDD alignment can be a series of both vertical and horizontal curves, so that a variety of obstructions can be avoided.

HDD has much less environmental impact over conventional pipeline trenching techniques. It is generally regarded by regulators as the Least Environmentally Damaging Practicable Alternative (LEDPA). The process affords maximum depth of cover for the pipeline, therefore providing maximum protection and minimizing maintenance costs. With traditional cut and cover crossings, the pipeline is subject to exposure due to river or beach scour. The depth of cover provided by HDD precludes this problem. The HDD construction process does not impede waterway traffic and has a relatively short and predictable construction time frame. Lastly, HDD in some cases may be the least expensive construction alternative when crossing major waterbodies and associated wetlands (GRI, 2000b). The primary environmental impact of HDD on aquatic environments is from the uncontrolled subsurface discharge of drilling fluids when pressurized drilling muds follow fractures up through the soil profile and into the surrounding environment. These discharges – hereafter referred to as inadvertent returns – are discussed in more detail in the Environmental Impacts section of this paper and in the BMP Manual.

Drill fluid

As in any drilling operation, the HDD process uses large quantities of engineered fluids to assist the operation. The drill fluid is used to:

- Clean drill cuttings from the drill bit and transport of the cuttings to the surface;
- Stabilize flowing formations and protecting against collapse;
- Protect against loss of drill fluid to surrounding underground formations by forming a low permeability cake on the wall of the drill hole;
- Provide excavation of soft underground formations from hydraulic energy in a jet bit;
- Provide mechanical energy for rotation of the drill bit in a down-hole mud motor;
- Lubricate down-hole tools and equipment; and
- Provide lubricity to the pipeline during pull back into the drilled hole.

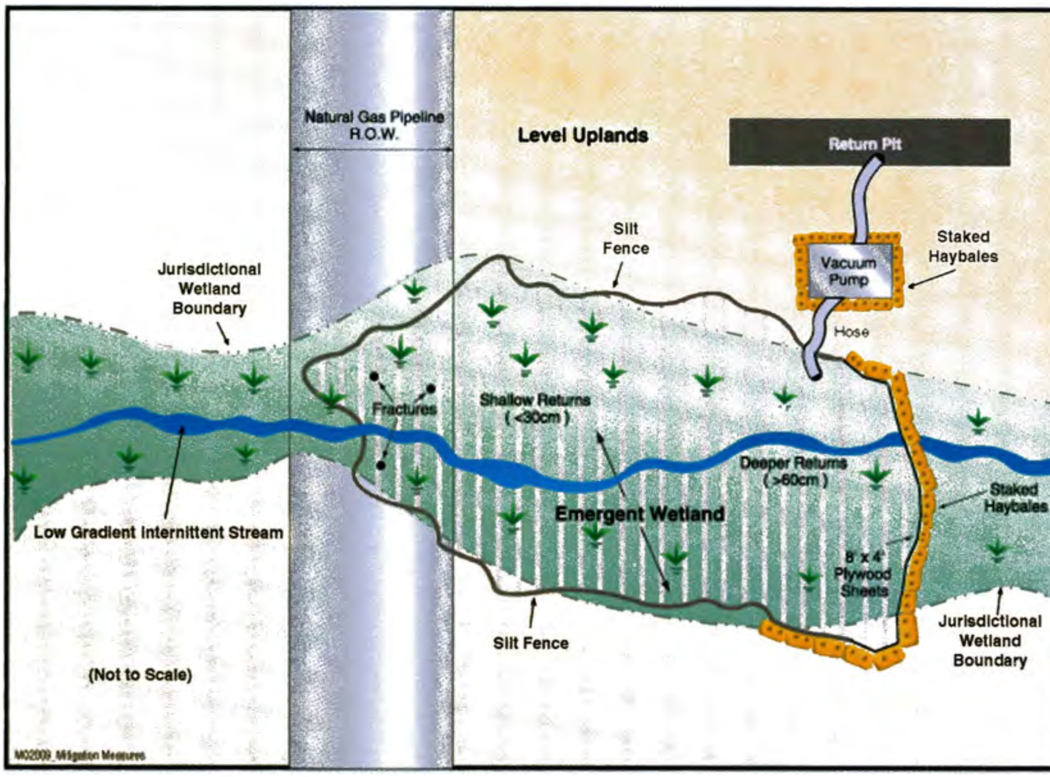

Fig. 1. Example of HDD profile (adapted from Hair et al., 1995).

The drill fluid is usually a mixture of fresh water and bentonite. An adequate source of fresh water should be identified near the drill site, as consumption rates can range between 300 and 700 gallons-per-minute (gpm) during reaming operations. Bentonite is natural clay that is extremely hydrophilic and hence high swelling. This swelling increases viscosity for cuttings transport and creates an impervious coating on the wall of the borehole for stability. Certain polymers may also be used which enhance the benefits of bentonite in the slurry. These polyanionic polyacrylimides are nontoxic and ecologically inert. Other additives may include Mixed Metal Hydroxides, which are not toxic when diluted and meet EPA requirements.

HDD process

The HDD operation is comprised of three stages: pilot hole drilling, prereaming, and pullback. These stages are briefly described below:

- Pilot hole drilling: The drilling of the pilot hole along a predetermined alignment and profile is accomplished using a steerable drilling assembly and electronic survey techniques. The time to drill the pilot hole is variable and dependent on the ground conditions and drilled length;
- Prereaming: Once the pilot hole is complete and in an acceptable location, the hole is enlarged to a diameter sufficient to accommodate the pipeline. The final hole diameter generally is 12 inches greater than the product pipeline and up to 1.5 times the diameter of the product pipeline. The larger ream diameter facilitates pullback of the pipeline string into the drilled hole. Enlarging the hole is accomplished by pulling successive cutters of increasing diameter through the hole; and
- Pullback: Once the drilled hole is enlarged and is determined to be stable and clean, pull back of the product pipeline is performed. The product pipeline has been prefabricated on the exit side opposite the drilling rig. The pipeline is usually placed on rollers as it is pulled into the drilled hole. The pipeline may be cradled through a vertical curve to achieve the proper angle at the exit point. Pull back of the pipeline proceeds continuously until the leading edge of the pipe reaches the entry point at the drill rig. If pull forces rise to rig capacity, the pipeline string is generally retracted from the drilled hole towards the exit point. The hole is usually reconditioned, either by another reaming pass and/or a cleaning pass with a smaller diameter reamer, before a second pullback attempt is made.

RESOURCES SUITABLE FOR HDD

HDD has emerged as an alternative technology for installing natural gas transmission lines, electric utility lines, fiber optic cables and other utilities under ecologically-sensitive areas as well as under social infrastructure. Typically, HDD provides a very stable and virtually maintenance-free crossing with minimal to no disturbance, which can make permitting requirements simpler. HDD provides a number of practical construction advantages over more conventional crossing methods. With HDD, difficult or surficially unstable terrain and crossing locations that have limited access or which have conflicting uses can be avoided. Five types of crossings that typically are encountered and that are suitable for HDD are the following:

- Waterway crossings such as rivers, streams, canals, levees, bays, bayous, ponds, harbors, water reservoirs, estuaries, lakes and shore approaches;
- Wetland crossings such as marshes, swamps, fens, bogs and similar areas;
- Social infrastructure crossings such as roadways, highways, railroads, airport runways and congested urban areas. HDD is also suitable for crossings under or near historical buildings and archaeological, historical, or paleontological sites;
- Sensitive wildlife habitat crossings such as areas where threatened or endangered species reside as most of the work occurs well below ground surface; and
- Crossings in the vicinity of other utilities such as congested utility ROWs, as well as crossings near municipal, industrial, or residential water intakes.

CONSTRUCTION BMPS

Design profile and depth of cover

Design of the drill path profile begins with an accurate elevation survey of the drill alignment and identification of obstacles both above and below ground. The accuracy of this survey also dictates the accuracy of the as-built location of the pipeline. The design drill profile is a series of straight tangents and large radius curves (curvature is relative to the flexibility of the installed line pipe). Entry angles generally vary between 8 and 20 degrees from horizontal. A curve is introduced to bring the profile to an elevation that will provide the designated depth of cover. Longer crossings usually have an extensive horizontal straight segment at the designated depth of cover. The drill profile is then curved upward to an angle between 5 and 12 degrees from horizontal.

Once the profile of the drill alignment is documented, then a determination of the depth of cover under the obstacles is made. In the case of a river, an analysis should be made to determine predicted scour of the river bottom and stability or movement of the riverbanks over the design life of the pipeline. A minimum recommended depth under the deepest channel of a river is 20 feet. Another environmental concern that affects depth of cover consideration is the risk of inadvertent returns along the drill alignment. In a sensitive wetland environment, it is recommended to maintain at least 40 feet of cover.

Geomorphological variables and/or limitations affecting selection of HDD

Topography and hydrography

Because HDD technology limits the construction footprint to either side of an obstacle, the technique is often applied in areas where the social costs of construction may be high (e.g., blocked streets, dangerous construction conditions) and where environmental sensitivity is intense (e.g., wetlands, forests, endangered habitat zones). The topographic layout often dictates the arrangement of the construction operations. For instance, it is difficult to arrange heavy equipment on a hillside and man-made obstructions (buildings, wharves, etc.) may influence certain site selections. The hydrography can dictate where wetlands may occur and affect the design of the crossing by limiting workspace or requiring alternate methods.

Geologic setting

An understanding of the site geology is essential in planning an effective HDD installation. The types of ground conditions and homogeneity depend on the process by which the strata were deposited. When drilling in clay and cohesive soils, it is possible to achieve an open hole condition. Cohesive soils are ideal for the HDD process, because the material is easily cut and the hole remains open for the pipeline pullback. Granular material is more of a challenge for the HDD process. In loose sand, the mechanical action of the cutters and injection of the bentonite drill slurry causes the sand to decrease in strength. If the strength is low enough, the granular material actually behaves in a fluid-like manner. This liquefaction still allows the product pipeline to be pulled back.

Significant concentrations of large granular material (gravel, cobble, boulders) pose great risk to the HDD process, as these materials are typically not conducive to any underground construction. The large granular material is not readily transported out of the drilled hole by the drilling fluid and the particles are too heavy to behave as a fluid. The gravel and cobbles may remain in the drill path and become an obstruction, thereby precluding pullback of the pipeline. HDD installations in competent rock have been accomplished. These installations are generally costly due to low penetration rates. However, hole stability is usually not an issue.

ENVIRONMENTAL IMPACTS FROM HDD INADVERTENT RETURNS

As discussed above, the primary impact of HDD on wetlands and other sensitive aquatic environments is from inadvertent returns. However, impacts may also be incurred at the drill staging area, where vegetation must be cleared to facilitate drilling and a drilling mud return pit must be excavated. In addition, poor cleanup measures can also result in physical impacts to the surrounding areas. These discharges of drilling muds are known as inadvertent returns. Included in the subsections below are details regarding the impacts of inadvertent returns on aquatic environments, including impacts to vegetation, vertebrate and invertebrate species, water quality and wetland functions.

An inadvertent return occurs when the bentonite-based drilling fluid seeps up through fractures in the upper soil profile. In the case of wetlands, the drilling fluid may seep up into the saturated or inundated root zone. This may present some significant implications from a wetlands impact perspective, both physically and functionally, although generally for the short-term only. Inadvertent returns may ultimately trigger increased scrutiny under wetlands regulatory programs as the fluids may impact aquatic communities or constitute a deposit of dredged or fill material, thus necessitating a suitable contingency plan for muds management, and restoration of areas where returns occurred. Subsurface conditions that could be conducive to inadvertent returns include the following:

- Highly permeable soil such as gravel;
- Presence of rock joints or other subsurface fractures;
- Considerable differences in the elevations of entry and exit drill holes;
- Disturbed soil, such as piling and fill; and
- Areas where HDD vertical depth of cover is less than 40 feet (GRI, 2002a).

Clean-up of inadvertent returns

Field investigations have observed that the lack of cleanup of inadvertent returns can result in numerous impacts to wetlands (GRI, 2002b). These impacts include a change in microtopography thereby changing wetland hydrology, reduced vegetative cover for at least one to two growing seasons, no return of vegetation, changes in wetland vegetation communities and impairment of a wetland's sediment entrapment functions.

Physical disturbance from cleanup activities

Sandbags, hay bales, silt fences, cofferdams and vacuum trucks are commonly used in drilling mud containment and cleanup after an inadvertent return has occurred in wetlands, terrestrial areas and low-energy aquatic areas. Physical disturbance from cleanup activities, as well as the movement of equipment and workers, if not carried out correctly, may result in greater environmental damage than would occur from leaving the returns in place, depending on the surrounding environment.

Improper containment of inadvertent returns

Improper containment, either by not implementing containment measures, not containing the release immediately after detection, or improperly installing these measures, is likely to increase the surface area and volume of the release, thereby increasing cleanup costs and perhaps necessitating the stoppage of work. However, having containment and cleanup materials present when an inadvertent return occurs can minimize cleanup duration and effort (Luginbuhl and Gartman, 1995).

Proper cleanup of inadvertent returns

Field investigations evaluated the affects of drilling muds on vegetated wetlands that experienced HDD inadvertent returns (GRI, 2000). Evaluations of the vegetative community and wetland functions determined that the herbaceous vegetative community generally rebounded within one to two growing seasons after drill muds had been properly removed. Vegetative recovery occurred in terms of species richness, total percent areal cover and density of the overall plant community. Wetland areas that had been subject to disturbance from cleanup machinery showed no discernable, long-term impacts. If cleanup measures are improperly executed, greater damage can be incurred on the wetland system. These impacts can include the following:

- Physical damage to woody species, which generally take longer to recover than herbaceous species;
- Compaction of soils/ruts if heavy machinery needs to operate within wetland to clean up muds which can alter hydrology and vegetation rebound;
- Fuel or other hazardous materials being released from machinery; and
- Disturbance to aquatic species (e.g., reptiles, amphibians, fish), either through direct physical disturbance, destruction or impairment of habitat, or impairment of water quality.

Figure 2 depicts the proper mitigation measures for an inadvertent return in a vegetated wetland.

Receptors of environmental impacts

Inadvertent returns in wetlands and waterways have the potential to impact vegetation, vertebrate and invertebrate species and alter the receiving system's water quality and its functions. The impacts to each of these receptors are summarized below in Table 1. Potential impacts may occur independently, in combination, or not at all.

ENVIRONMENTAL BMPS

This section is intended for minimizing environmental impacts associated with HDD crossings and should not be implemented as a substitute for all pipeline environmental issues. This section is divided into two categories of BMPs: planning and permitting, and cleanup and restoration.

Planning and permitting for HDD crossings

- Determine site boundaries, preferred and alternate alignments;

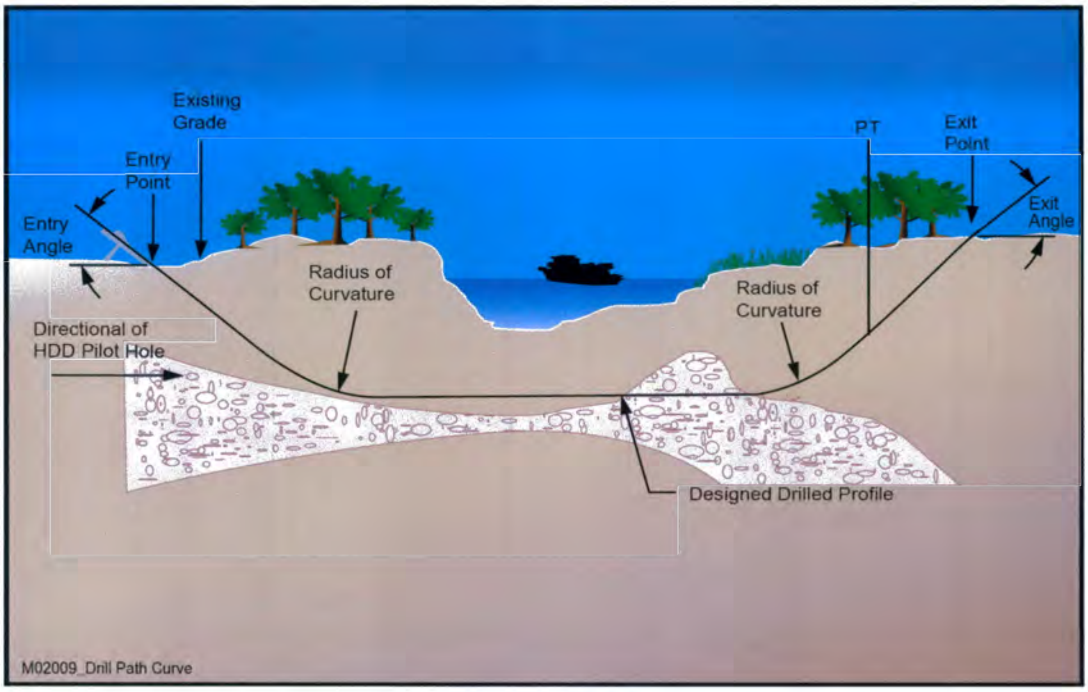

Fig. 2. Proper inadvertent return mitigation measures.

- Prepare preliminary profile design;
- Characterize sensitive areas within work space and crossing alignment;
- Establish protection measures;
- Identify potential pre-mobilization BMPs;
- Inadvertent return contingency planning; and
- Obtain permits and licenses.

Cleanup and restoration of inadvertent returns

This section presents the BMPs suitable for the containment and cleanup of inadvertent returns. These BMPs include equipment, as well as disposal, recycling and restoration considerations.

Mud containment, cleanup and removal BMPs

Table 2 summarizes the various environmental BMPs that are appropriate for containment and cleanup of inadvertent returns in both uplands and wetlands.

Muds disposal – land farming

- Land farming is the incorporation of leftover drilling fluids into upland areas of the pipeline right-of-way such as agricultural fields, quarries, or sand/gravel pits;
- Drilling fluids should be ploughed into the soils, so as not to create impermeable barriers upon hardening;
- Potential sites for land farming should be identified and evaluated and federal, state and local approvals obtained before the crossing has commenced;
- Paper documentation should be maintained for the disposal of drilling fluids. Records should indicate the volume of muds disposed of, the disposal date, the location of the disposal site, the property owner and the party that conducted the disposal; and
- Land farming is not a suitable disposal method for drilling fluids used in contaminated soil. If known contamination exists at the drill site or is highly suspected, drilling muds should be tested and disposed of in a manner consistent with applicable hazardous materials disposal regulations.

Muds disposal – landfill disposal

- Solids vs. liquids disposal: Inadvertent returns that have hardened cannot be disposed of with liquid returns. Disposal methods outlined in the contingency plan should take this into consideration. The requirements of disposal sites vary by locality; some segregate solids and liquids disposal, which can complicate disposal options;
- Cuttings should be disposed of at a solids disposal site. Paper documentation should be maintained of the volume of cuttings disposed of, the disposal location and the carrier;
- The drilling muds and cuttings dump site should be selected and noted in contingency plan before federal, state and local approvals are obtained;
- Maintain paper documentation. Records should indicate the volume of muds or cuttings disposed of, the location of the disposal site, landfill manager and the party that conducted the disposal; and
- The presence of contaminated soil at drill site will dictate the method of disposal. Drilling muds from a drill site with known contamination (e.g., heavy metals, chloride) or with high suspicion of contamination should be tested prior to disposal. Muds should be disposed of in a manner consistent with applicable hazardous materials disposal regulations.

Table 1. Summary of impacts to environmental receptors[1]

Receptor	Impact
Vegetation	– Smothering, which impairs photosynthesis, leading to diminished growth and colonization and mortality. – Decreased vegetation sustainability through reduced water infiltration in soil. – Shift in vegetative community through altered hydrology.
Vertebrates	
Fish	– Smothering of eggs. – Gill trauma. – Reduction in disease resistance. – Reductions in feeding levels. – Impaired growth. – Changes in territorial behavior. – Changes in spawning behavior.
Amphibians	– Egg damage or smothering. – Destruction of breeding areas.
Reptiles[2]	– Alteration of water quality. – Alteration of spawning and maturation areas, nesting areas and protective cover. – Alteration of adequate and reliable food supply.
Mammals[2]	– Alteration of water quality. – Alteration of migration routes, nesting areas and protective cover. – Alteration of adequate and reliable food supply.
Birds[2]	– Impacts to food supply. – Alteration of resting areas for migratory species.
Benthic Infauna	
Macro-invertebrates	– Alteration of habitat. – Decreased emergence rate of adult benthic invertebrates. – Barrier to burrow establishment. – Mortality via clogging of filter-feeding apparatus and digestive organs by suspended sediments.
Gastropods	– Smothering. – Increased toxicity of drilling muds to mollusks through use of pH-control additives.
Surface Soils	– Reduced soil permeability and water infiltration.
Water Quality	– Mortality of benthic organisms due to increased suspended solids. – Reduced primary productivity due to turbidity. – Decreased availability of oxygen leading to asphyxiation of organisms. – Altered pH due to the use of pH-control additives in drilling muds.
Wetland Functions	– Diminished flood storage capacity, increasing flood damage elsewhere. – Impairment of nutrient removal and transformation by vegetation. – Impaired sediment entrapment and stabilization ability. – Impaired water quality (see above).

[1]Summarized from GRI, 1998.
[2]No studies on impacts to these receptors have been conducted, however, it is assumed that these vertebrates will be adversely affected through indirect impacts.

Table 2. Quick reference chart to appropriate BMPs

Equipment	Purpose	When to use
	Containment Measures	
Silt Fencing	– Prevents migration of drilling muds in emergent wetland. – Intercepts/detains small amounts of sediments. – Act to dissipate velocity of overland flow. – Filters surface waters to minimize TSS impacts.	– In emergent wetlands. – Along banks and shore of waterways. – Not appropriate for use in waterways. – Not appropriate for drainage areas greater than two acres.
Hay Bales	– Detains small amounts of sediments. – Reduces runoff downslope.	– In vegetated wetlands. – Along banks and shore of waterways. – Not appropriate for use in waterways. – Not appropriate for drainage areas greater than one acre unless used in conjunction with silt fence. – Not always appropriate in sensitive areas as hay bales may introduce foreign seeds.
Sand Bags	– Containment of high volume inadvertent returns.	– For containment of high volumes where hay bales and silt fencing would be ineffective.

Table 2. (continued)

Equipment	Purpose	When to use
Floatation Boom with Siltation Curtain	- Containment of drilling muds in inundated areas with a likelihood for dispersal of returns by current or water flow. - Waterways with a water level is greater than one foot.	- Containment in a waterway (i.e., pond, bay, river, or stream). - Not appropriate for wetlands without water levels greater than one foot.
Plywood Sheeting	- 4 feet by 8 feet by ½ inch sheets used to contain pooled returns.	- Deeper inadvertent returns (greater than 1 foot) where hay bales, sand bags or silt fencing would be ineffective. - Best utilized when supported by hay bales. - In tidal wetlands where cleanup cannot be completed before incoming tides diffuse/spread the return.
	Cleanup Measures	
Excavator	- For excavation of containment pit at drilling rig site.	- For use in upland areas only.
Vacuum Truck	- Used to collect liquid inadvertent returns. - Immediate cleanup of bentonite muds before hardening. - Collects inadvertent returns for recycling or off-site disposal (e.g., land farming or dump site).	- Removal of muds from inadvertent return area to designated upland pit or tank at the drilling rig site. - Should be located in an upland area, or if necessary to enter wetland, swamp mats should be utilized to minimize disturbance of the soil profile.
Dump Trucks	- Removal of bentonite muds to disposal area.	- Not for use in sensitive areas. - For use in upland areas only, to be loaded by wheelbarrows.
Frac Tanks	- For storage of bentonite muds when sump pit at rig site is not large enough (or a large enough sump pit could not be excavated at the site) to contain inadvertent returns before disposal.	- Should be located in an upland location.
Swamp Mats	- Minimize sedimentation in waterway. - Minimize sinking of equipment into substrate. - Minimize soil compaction and damage to shallow root zone.	- For use in small to medium waterways where disruption of substrates is a concern, but fish passage is not. - For use to abate soil disturbance in vegetated wetlands when heavy equipment (e.g., excavators, vacuum trucks) is required to enter a wetland or waterway for cleanup operations. - Not for use in wetlands with woody vegetation.
Plywood Sheeting	- To create narrow walkways for workers and equipment (wheel barrows, small loaders) access into sensitive areas.	- For use in sensitive areas (vegetated wetlands such as marshes, swamps, bogs) where impact from foot traffic and smaller equipment should be minimized to prevent physical damage to plants and surface soils.
Brooms and Rakes	- For manual removal of bentonite muds from vegetated areas.	- Typically used after the majority of bentonite muds have been removed by pump or manually with shovels. - Used to isolate residual muds for pumping. - Used in sensitive areas to minimize impact to vegetation from shovels, etc.
Squeegees	- Removal of residual bentonite from vegetation.	- Used in sensitive areas to minimize impact to vegetation from shovels, etc. - Used to isolate residual muds for pumping. - Used for aesthetics.
Shovels	- Removal of gelled or thickening bentonite muds.	- Not for use in areas of federally- or state-listed endangered or threatened vegetation.
Wheelbarrows	- Manual transport of bentonite muds gathered by shovel, broom, or rake.	- Removal of bentonite muds in sensitive areas or other areas that will not support the use of excavators or small loader.
Snowshoes	- To access areas of deep returns prior to determining final cleanup method. - Minimize impact of foot traffic of cleanup personnel on vegetation. - To facilitate manual movement through areas of deep returns where heavy machinery has been prohibited.	- For use in areas of rare or otherwise sensitive vegetation. - For use in sensitive areas such as bogs or tidal wetlands to minimize soil compaction and trampling of vegetation caused by foot traffic.

Muds disposal – inadvertent return recycling

- Inadvertent returns are typically recycled when they occur near the drilling rig and the effort to recapture the drilling muds is less than the disposal cost;
- Recycling is not suitable when inadvertent returns have been diluted by brackish water or water of an unsuitable hardness or pH. Recycling is suitable for inadvertent returns occurring in uplands, forested or scrub-shrub wetlands, emergent wetlands and bogs;
- In rare occasions the drill mud builds up a significant percentage of fines, which cannot be removed by the recycling equipment. In such cases, the mud is disposed of and not re-used. Also, drilling muds contaminated by drilling in contaminated soils cannot be recycled;
- Recycling of drilling muds is recommended for most HDD projects as it reduces the supply of muds needed, water demand and disposal costs. Recycling of muds is recommended where the volume and cost of muds disposal is greater than the cost of a recycling system;
- Recycling systems separate cuttings from drilling fluid returns through recirculation and screening;
- Recycled muds should be disposed of when the carrying capacity for cuttings is diminished and the mud weight has increased; and
- Contingency plan and permit applications should specify that drilling muds will be recycled, where predictable.

Restoration

Upon completion of the HDD installation, the site should be restored to pre-existing conditions, including restoration of pre-existing topography and vegetation. A pre-approved conceptual/generic restoration plan should be available prior to commencement of work. The restoration plan should contain the following components:

- Backfilling of muds return pit to pre-existing grades;
- Revegetation of drill rig staging area using the appropriate vegetation;
- Removal and proper off-site disposal of sedimentation/erosion controls once the crossing has been completed and the soils have become re-vegetated; and
- Removal of inadvertent return containment BMPs immediately after cleanup has been completed.

Post-construction monitoring and sampling

Post-construction monitoring and sampling may be appropriate for crossings that experienced inadvertent returns. Also, monitoring programs may be requested by state environmental regulatory agencies as a mitigation condition. Monitoring typically occurs for one to two years after restoration. Monitoring programs may include seasonal vegetation monitoring, aquatic invertebrates sampling, soil profile inspections and functional impact assessments (including wildlife and aquatic species habitat). A detailed monitoring program should be designed and approved prior to commencement of work. A pre-approved monitoring plan will prevent ambiguities associated with duration, frequency, and overall effort of monitoring, reducing overall project costs.

CONCLUSION

The BMP Manual summarized in this paper represents the culmination of five years of research funded by the Gas Technology Institute. The Manual was created to be a comprehensive decision-making tool for HDD planning and construction, as well as BMPs for the prevention and management of returns in ecologically-sensitive areas. A copy of the BMP Manual can be obtained by contacting the authors.

REFERENCES

GRI. 1998. Literature Survey for Evaluating the Effects of Muds on Wetlands from Horizontal Drilling Topical Report. Topical Report prepared by ENSR for the Gas Research Institute. GRI-98/0190. December.

GRI. 2002a. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: The Relationship of Subsurface and Geophysical Conditions to Inadvertent Returns. Topical Report prepared by ENSR for the Gas Research Institute. GRI-01/0233.

GRI. 2002b. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: Phase II Field Investigation. Topical Report prepared by ENSR for the Gas Research Institute. GRI-02/0145.

GRI. 2000. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: Field Investigations. Topical Report prepared by ENSR for the Gas Research Institute. GRI-99/0236. April.

J.D. Hair and Associates, Inc., Louis J. Capozzoli & Associates, Inc. and Stress Engineering Services, Inc. 1995. Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide. Prepared under the sponsorship of the Pipeline Research Committee at the American Gas Association. April 15.

Luginbuhl, K. and D. Gartman. 1995. Pipeline Construction in Wetlands: Lessons Learned. Underground Construction. July.

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Inadvertent Slurry Returns during Horizontal Directional Drilling: Understanding the Frequency and Causes

Eric R. Skonberg, Carl E. Tammi, Andrea M. Desilets, and Vipul Srivastava

Horizontal Directional Drilling (HDD) is an innovative and attractive construction method for installing pipelines and utilities within rights-of-way. Regulatory agencies often consider HDD as the least environmentally disruptive alternative because construction operations can be isolated from environmentally sensitive areas. However, bentonite slurries used in HDD are known to inadvertently migrate to the surface, which may introduce foreign material into wetlands or increase turbidity in surface waters. The Gas Research Institute (GTI) sponsored a survey of large HDD installations to identify the frequency and possible causes of inadvertent returns. Survey results would provide planners information to aid in critical decision making. Questionnaires were sent to HDD Contractors to assimilate information about crossing parameters and inadvertent return details. Ultimately, 54 individual HDD installations of various lengths and in an assortment of geotechnical conditions were studied. Inadvertent return events occurred on approximately half of the HDD installations. Inadvertent returns occurred most frequently within 200 ft. of the entry or exit point and where there was less than 40 ft. of overburden. No correlation was observed between lack of normal returns, slurry properties, or pumping rates and the inadvertent return events. Disturbed ground (tree roots, pilings, burrows, etc.) increased the likelihood of inadvertent returns. Inadvertent returns are a phenomenon which cannot be ignored. Construction rights-of-way should be obtained for remedial clean-up in the first and last 200 ft. of any HDD alignment. Most events studied produced manageable amounts of material that can be contained and disposed without interrupting the construction operations.

Keywords: Horizontal directional drilling, HDD, pipelines, inadvertent returns, frequency, slurry, disturbed ground

INTRODUCTION

HDD is an innovative and much-used technology for the installation of natural gas pipelines under waterways, wetlands, and other obstacles. Increased environmental awareness has boosted the use of HDD where it is now the method-of-choice by regulatory agencies for construction in sensitive areas. Because the construction footprint of HDD generally is limited to work areas on either side of the obstacle, HDD avoids disturbance to the adjacent wetlands, streambeds, and waterway traffic. A far greater depth of cover is afforded by HDD promoting pipeline security. Turbidity limits and monitoring requirements of conventional "cut & cover" techniques can be avoided. This allows regulatory permitting to proceed in a more straightforward manner, as HDD is often considered the Least Damaging Practicable Alternative (LEDPA).

The HDD process uses the flow of large volumes of drilling slurry. The slurry provides the following:

- Removal of cuttings from the drilled hole;
- Borehole stability – especially in granular materials; and
- Cooling and lubrication of the cutting tools.

In large diameter installations (24 inches and greater), the flow rates can range from 400 to 600 gallons per

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minute (gpm). Much of the slurry and cuttings return to pits at the entry and exit points of the borehole. Here the cuttings can be separated from the slurry and the slurry may be conditioned and reused. Generally, the slurry is a mixture of freshwater and bentonite. Bentonite is a natural clay that is extremely hydrophilic and high swelling. This swelling increases viscosity for cuttings transport and creates an impervious coating on the wall of the borehole for stability. Certain polymers may also be used to enhance the benefits of bentonite in the slurry (i.e., maintain or increase viscosity), often requiring half the typical quantity of bentonite. These polyanionic polyacrylimides are nontoxic and ecologically inert; many of which are food grade and are added as thickeners. Other additives may include mixed metal hydroxides (MMH) (for increased cuttings suspension under low viscosity), which are not toxic when diluted and meet EPA requirements.

Inadvertent returns occur when the drill slurry seeps up through fractures in the upper soil profile and, in the case of wetlands, potentially into the saturated or inundated root zone. Inadvertent returns are occasionally referred to as "frac-outs." However, a forensic analysis of HDD by the Construction Productivity Advancement Research (CPAR) program of the U.S. Army Corps of Engineers (ACOE) indicated that a hydrofracture, if it occurs, is usually a minor event and is limited to shallow portions of the drill profile (Staheli et al., 1998).

The implications of inadvertent returns potentially entering wetlands may ultimately trigger increased scrutiny under wetlands regulatory programs. Regulatory agency staff may consider bentonite and cuttings in wetlands a deposit of *dredged or fill material*, or perceive that other biological impacts will be incurred.

GTI has previously collected and assessed data on the effects and frequency of inadvertent returns in a *Professional Screening Survey/Permit Condition Review* (GRI, 1999a). This work identified contacts in the HDD industry, and solicited experiences and perceptions of inadvertent return occurrences. Those questioned in the survey included regulatory agency personnel, HDD contractors, and natural gas transmission line (NGTL) environmental staff. A conclusion drawn from the work indicates that regulatory agency representatives perceived a much lower frequency of inadvertent returns than NGTL companies and HDD contractors. Most HDD contractors and NGTL respondents believed that inadvertent returns were an inherent risk during HDD crossing (GRI, 1999b).

In reviewing the data gathered from a variety of HDD installations, the goal for this analysis was to gain a better understanding of the information needs and predictability of inadvertent returns. Specific objectives included the following:

- Determining the frequency of inadvertent returns in HDD installations;
- Developing an understanding of surficial soil types, which may lead to inadvertent returns and establishing the framework for understanding the probability that an inadvertent return will occur; and
- Establishing a correlation between the drill profile design parameters (depth of cover, hole diameter, drill length, etc.), which may affect the likelihood of inadvertent returns.

DATA ACQUISITION & ASSIMILATION

Information about inadvertent return occurrences was solicited for a variety of HDD projects. Questionnaires were submitted to eleven major HDD contractors based in the U.S. The contractors selected had significant work experience on larger HDD installations. As the criteria for the data assimilation were to focus on crossings greater than 750 feet, contractors with smaller installation experience were not solicited.[1] These eleven contractors were solicited to provide a diversity of data based on geography, ground conditions, and installation sizes. The solicitation letter described the research project as funded by GTI and provided a brief outline of what was to be accomplished. An explanation of the data requested in the questionnaire is provided below.

1. General Background – Information about the owner/contractor, crossing location, and approximate dates of construction was requested. Due to the regulatory sensitivity of inadvertent returns, this information was considered optional;
2. Crossing Description – Only data on HDD crossings longer than 750 feet were requested to preclude shallow installations. It was determined that crossing dimensions (length by diameter) could lead to correlations that inadvertent returns are dependent upon crossing dimensions. Geotechnical information was also requested to analyze correlations between soil types and incidence rates of inadvertent returns;
3. Drilling Fluids Description – Details of drilling fluid composition and typical viscosity were requested to see if use of bentonite extended with polymers or with MMH additives reduced the frequency of inadvertent returns. The typical pumping rate for each drilling stage was also requested to determine any correlation between the drill stage pump rate and inadvertent return occurrence during that stage; and

1 Mini HDD crossings (less than 750 feet) generally are conducted in congested and urban environments. The depth requirement of the electronic survey tools allow for more shallow profiles, where ground conditions are usually disturbed by other utilities. Inadvertent returns are considered more frequent for these crossings. Longer crossings of rivers, shorelines, and associated wetlands are conducted with electronic steering tools, which are not dependent on depth for survey readings.

4. Specifics on Inadvertent Return Events – Additional information was requested if inadvertent returns occurred during the crossing. This request included a more precise location along the drill path of the release (i.e., distance from the entry or exit hole), the drilling stage at the time of release, the estimated volume and areal extent of the release, and what, if any, containment/clean-up techniques were deployed.

A total of 110 questionnaires were sent out. Completed questionnaires were received for 63 HDD projects. Of the questionnaires received, nine were discarded due to either incomplete data or duplicate data from multiple crossings at the same location. The data on the remaining 54 HDD projects were ultimately utilized.

FINDINGS

Once all the questionnaires were received, the data were reviewed and interpreted, recording correlations and differences. The following summarizes the general information provided:

- Crossings occurred in ten states, including Alabama, California, Florida, Georgia, Louisiana, Ohio, Oregon, South Carolina, Texas, and Virginia. In addition, information from two international projects was provided;
- Crossing types included crossings of rivers, creeks, bays, lakes, shore approaches, roadways, and railroads. River crossings and shore approaches were the most common crossing types reported in questionnaires (43 percent and 31 percent of reported crossings, respectively);
- The large majority (80 percent) of the projects had a geotechnical investigation prior to construction. The number of geotechnical exploratory borings taken ranged from one to six;
- The surficial soil types ranged from alluvial to hard rock. Clay/silt was encountered on 70 percent of the crossings, sand/gravel was encountered on 59 percent, rock was encountered on 35 percent, and cobble/boulder was encountered on six percent;
- Pipe diameters ranged from five inches to 41 inches. There were also several bundled installations, and a nominal diameter was used for comparison purposes. The average diameter was 20 inches and large diameters (24 inches and greater) comprised 44 percent of the crossings;
- Drilled lengths varied from 750 feet to 5,500 feet. The average crossing length was approximately 2,900 feet;
- Elevation change between entry hole and maximum-drilled depth of the 54 crossings averaged 74 feet;
- Typical viscosity ranged from 60 to 100 seconds, with the average being 74 seconds;[2] and
- Extended bentonite[3] was used during 81 percent of the crossings; Wyoming bentonite was used during 19 percent of the crossings, and MMH additive was used on two percent of the crossings.

These crossings represented a diversity of surficial soil types, geography, pipe diameter, and drilled length. Table 1 provides some of the relevant statistics of the completed projects.

Frequency of inadvertent returns

Of the 54 responses reviewed, inadvertent returns were realized on over half of the crossings (52 percent). Half of the inadvertent return events occurred during creek and river crossings. Creek and river crossings comprise 43 percent of the 54 questionnaires received. This empirical evidence suggests that inadvertent returns have a strong probability of occurring and careful contingency planning for containment and clean up should be in place for all HDD installations. Table 2 below presents general characteristics of the inadvertent returns reported. Crossings with inadvertent returns realized were analyzed for correlations with drilling stage, depth of cover, crossing length, crossing diameter, drilling fluids parameters, soil conditions, and presence of disturbed ground.

Key commonalities of inadvertent return occurrences

A review of the 28 questionnaires reporting inadvertent returns determined similarities between occurrences. These similarities have been categorized and are discussed in detail in the following subsections.

Drilling stage

Inadvertent returns were reported in all stages of the drilling operation, through pilot hole drilling, pre-reaming, and pullback of the product pipe. More than 50 percent of all inadvertent returns occurred during more than one stage of drilling. However, the first indication of inadvertent returns appeared most frequently (61 percent) during the pilot hole drilling (see Fig. 1). Fourteen percent of the crossings experienced inadvertent returns solely during pilot hole drilling. Seven percent of the crossings experienced inadvertent returns during pilot hole drilling and pre-reaming, and 14 percent of the crossings experienced inadvertent returns during pilot hole drilling and pullback. Inadvertent returns occurred solely during the pre-reaming stage of drilling for 29 percent of crossings and during only the pullback stage for four percent of crossings. Twenty-five percent of returns occurred during all three stages.

The frequency of occurrences based on drilling stage indicates that the majority of inadvertent returns occur during pilot hole drilling and, 25 percent of the time, continue through all three drilling stages. Where inadvertent returns were realized in all three drilling stages, sandy soils were present and the depth of cover ranged from 10 to 35 feet, averaging 15 feet.

2 The viscosity of the drill slurry is a measure of the resistance of a liquid to flow and generally is an indication of the mix ratio. Viscosity is reported in seconds, as measured by a Marsh funnel.

3 Extended bentonite is bentonite mixed with polymers that can maintain or increase bentonite viscosity, often using only half the typical amount of bentonite.

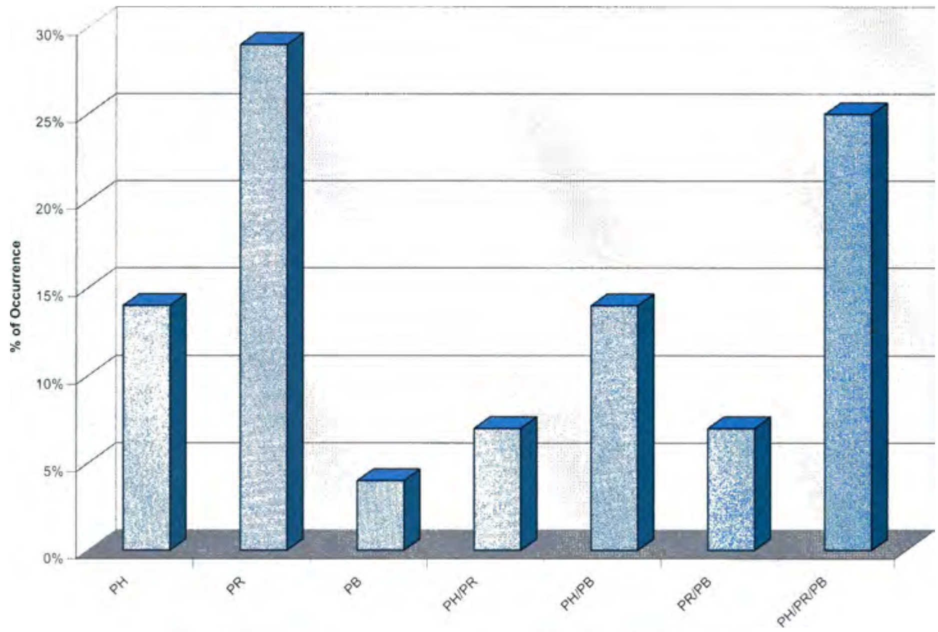
Table 1. Survey response information

Crossing type: Number	Geotechnical investigation conducted?: Number	Prevalent soil type: Number	Drill dimensions	Mud used: Number	Typical viscosity
All questionnaires					
Creek/River: 23 Lake/Bay/Bayou: 6 Shore Approach: 17 ROW/Roadway/RR: 6 Other: 2	Yes: 43 (1 to 6 borings) No: 11	Sand/Gravel: 32 Clay/Silt: 39 Cobble/Boulder: 3 Rock: 19	Diameter range: 5 to 41 inches (average = 20 inches) Length range: 750 to 5,500 feet (average = 2,890 feet)	Extended bentonite: 44 Bentonite: 10 MMH: 1	60 to 100 seconds (average = 74 seconds)
Questionnaires reporting inadvertent returns					
Creek/River: 14 Lake/Bay/Bayou: 4 Shore Approach: 8 ROW/Roadway/RR: 2 Other: 0	Yes: 26 (1 to 6 borings) No: 2	Sand/Gravel: 20 Clay/Silt: 25 Cobble/Boulder: 1 Rock: 8	Diameter range: 5 to 41 inches (average = 22 inches) Length range: 750 to 5,300 feet (average = 3,096 feet)	Extended bentonite: 25 Bentonite: 3 MMH: 0	60 to 100 seconds (average = 74 seconds)
Questionnaires not reporting inadvertent returns					
Creek/River: 9 Lake/Bay/Bayou: 2 Shore Approach: 9 ROW/Roadway/RR: 4 Other: 2	Yes: 17 (2 to 6 borings) No: 9	Sand/Gravel: 12 Clay/Silt: 14 Cobble/Boulder: 2 Rock: 11	Diameter range: 5 to 24 inches (average = 17 inches) Length range: 900 to 5,500 feet (average = 2,664 feet)	Extended bentonite: 19 Bentonite: 7 MMH: 1	60 to 100 seconds (average = 74 seconds)

Table 2. Summary of inadvertent returns

Drilling activity during IR[1]: Number	Distance from entry or exit hole	Depth of drill profile at IR Site	Soil type at IR Site: Number	Disturbed ground features at IR site: Number	Normal returns during IR[2]: Number	Estimated volume of IR
Pilot Hole: 17 Pre-ream: 19 Pullback: 14	Range: 40 to 2,700 feet (average = 690 feet)	Range: 10 to 100 feet (average = 27 feet)	Sand: 19 Clay/silt: 4 Fill: 5 Other: 2	Roots: 8 Oyster bed: 2 Burrows: 2 Piling: 6 Fill: 2 Previous HDD attempt: 3 Other: 3 None: 2	Yes: 25 No: 3	Range: 84 to 84,000 gallons

[1] Drilling activities add up to more than 28 because 54 percent of reported inadvertent returns occurred during more than one drilling stage.
[2] Normal returns means normal flow from the borehole at the time of the inadvertent return event.



Single Drilling Stage Multiple Drilling Stage

PH = Pilot Hole; PR = Pre-reaming; PB = Pullback.

Fig. 1. Inadvertent return occurrences by drilling stage.

Table 3. Characteristics of inadvertent returns (IR) within 200 feet of entry or exit hole

Crossing type	Pipe diameter (inches)	Crossing length (feet)	Distance from entry/exit (feet)	Depth of IR (feet)	Soil type	Disturbed ground present?
Creek	30	1,850	50	10	Sand	No
Creek	30	3,100	50	10	Sand	No
River	10	4,650	50	10	Topsoil	Yes; Burrows/roots
River	30	4,750	50	10	Sand	No
River	24	1,300	75	10	Sand	No
Creek	36	1,600	75	12	Sand	No
Lake	24	1,600	<100	<50	Sand	Yes; Tree roots/piling
Roadway	16	2,350	100	20	Fill	Yes; Rock interface
River	10	4,530	100	30	Sand	Yes; Tree roots
Creek	28	1,675	<200	<40	Fill	Yes; Reclaimed wetland: sand/rip rap
Bayou	24	750	200	20	Clay	Yes; Burrows
Shore approach	41	2,500	200	50	Sand	Yes; Previous HDD attempt
Bay	24	2,850	200	60	Fill	Yes; Piling/fill
Bay	26	2,850	200	60	Fill	Yes; Piling/fill
River	30	5,000	200	25	Sand	Yes; Roots
Roadway	30	5,300	200	<50	Silt/Sand	No

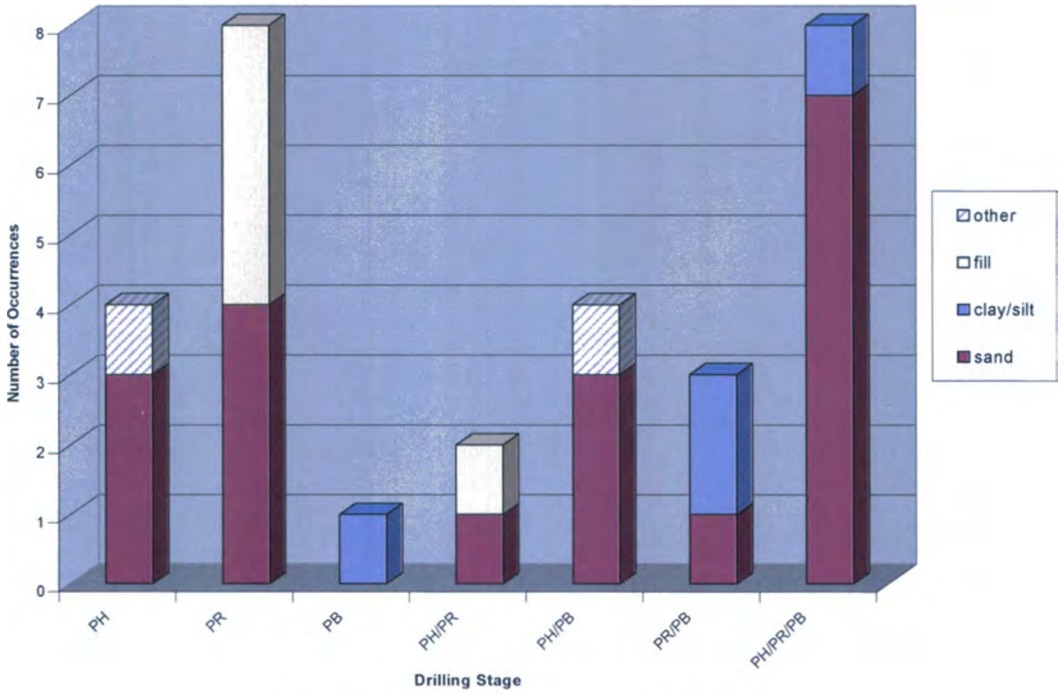
Depth of cover

Inadvertent returns were realized with depth of cover ranging from 10 to 100 feet. Those crossings with less than 40 feet of cover at the inadvertent return location comprised 61 percent of the inadvertent return events.

Sixty-seven percent of the inadvertent returns occurred within 200 feet of either the entry or exit pits and 32 percent of inadvertent returns occurred within 100 feet of the entry/exit pits. These areas are the shallowest parts of each crossing and have reduced overburden pressure. Half of the inadvertent returns that occurred within 200 feet of the entry/exit hole had a depth of cover of 20 feet or less and 69 percent had a depth of cover of 40 feet or less (see Table 3). Soil type at these locations consisted of either sand or fill (see Fig. 2).

Crossing length

It is often suggested that the length of the drilled crossing increases the likelihood of inadvertent returns. In longer crossings, there is additional need for a hydraulic "push" of slurry and cuttings to the entry/exit pits. This increased hydraulic gradient creates greater annular pressure and may increase the chances for



PH = Pilot Hole; PR = Pre-reaming; PB = Pullback.

Fig. 2. Soil type at inadvertent return occurrence by drilling stage.

Table 4. Typical crossing characteristics (with and without inadvertent returns)

Crossing characteristics	Crossings with inadvertent returns	Crossings without inadvertent returns
Pipe Diameter Range	5 to 41 inches	5 to 24 inches
Mean Diameter	22 inches	17 inches
Crossing Length Range	750 to 5,300 feet	900 to 5,500 feet
Mean Length	3,096 feet	2,664 feet

inadvertent returns. However, the questionnaire data shows that crossings where no inadvertent returns were realized range in length from 900 to 5,500 feet and those with inadvertent returns ranged from 750 to 5,300 feet in length. The average length of crossings where no inadvertent returns were realized was only 14 percent less (2,664 feet vs. 3,096 feet) than those crossings with inadvertent returns. These data suggest that increased crossing length slightly influences the frequency of inadvertent returns. Table 4 presents the range and average crossing information for crossings with and without realized inadvertent returns.

Pipe diameter

Pipe diameters without inadvertent returns ranged from 5 to 24 inches and crossings with inadvertent returns ranged from 5 to 41 inches. In those crossings with inadvertent returns, the diameter averaged approximately 22 inches, while those with no returns averaged approximately 17 inches. Twelve of the 28 crossings with inadvertent returns (43 percent) had crossing diameters greater than 24 inches, which was the upper value in the range of diameters for crossings without inadvertent returns. These data indicate that the diameter of the product line, where the resulting drill diameter is often 12 inches or 1.5 times greater than the diameter of the product line, does significantly increase the chances of inadvertent returns.

Drilling fluids

All crossings used either bentonite or extended bentonite with marsh funnel viscosity ranging between 60 to 80 seconds. No reasonable conclusion can be drawn as to a correlation between slurry characteristics and inadvertent returns. There was also no discernable difference between slurry pumping rates during various drilling stages and crossings with and without inadvertent returns.

Normal returns were being realized to either the entry or exit pits in 89 percent of the inadvertent return occurrences. It is often thought that lost returns are a precursor to inadvertent returns to the surface; however, the survey data does not support this conjecture. There does not appear to be a correlation between inadvertent returns and the absence of normal returns. Therefore, the monitoring of return rates is not recommended for detection of an inadvertent return.

Geological and underground conditions

Distinct differences between soil type at crossings with and without realized inadvertent returns were observed. The majority of inadvertent returns occurred in alluvial soil (sand, gravel, clay, and silt). Although

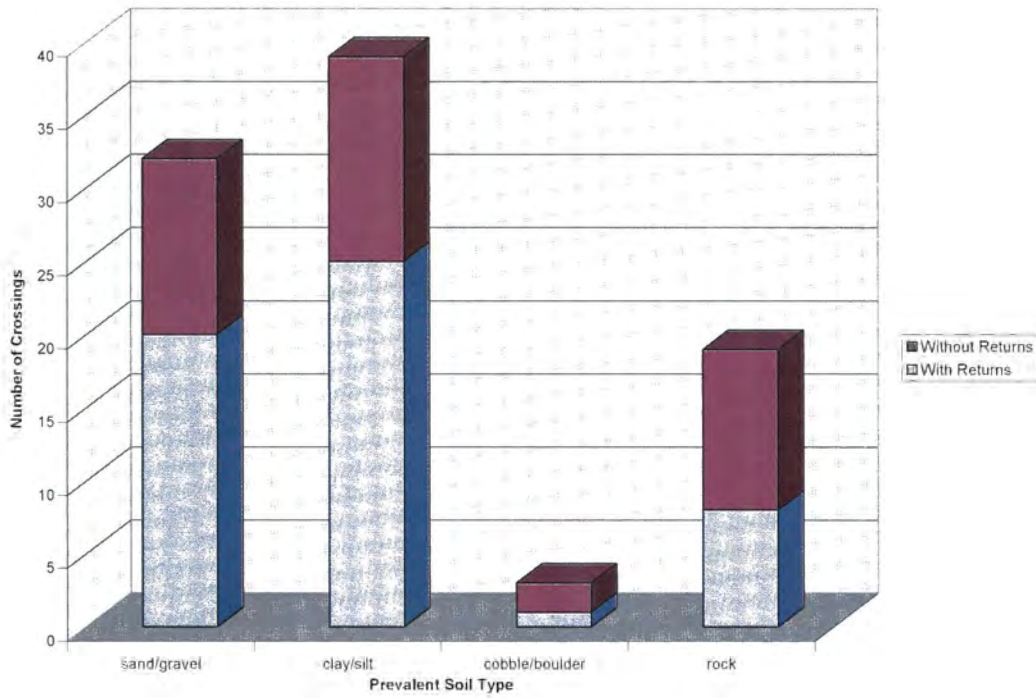


Fig. 3. Prevalent soil types present at crossings with and without inadvertent returns.

Table 5. Soil characteristics at inadvertent return sites

Soil type	Number of occurrences	Disturbed ground	
		Yes	No
Sand	15	10	5
Sand/Gravel or Sand/Cobble	2	2	0
Sand/Clay	2	2	0
Sand/Silt	1	0	1
Clay	1	1	0
Silt	1	1	0
Fill	5	4	1
Marine deposits	1	1	0
Topsoil	1	1	0
Total	28	21 (75%)	7 (25%)

fewer cobble and rock crossings were reported than alluvial-soil crossings, more than half of these crossings did not realize inadvertent returns (see Fig. 3).

All but two of the 28 questionnaires reporting inadvertent returns had a geotechnical report available for consultation before construction. The general soil descriptions were varied from alluvial (sand, silt, and clay) to rock. Interestingly, in the description of soils at the point of inadvertent returns, all but one of the descriptions was of granular material (sand, gravel, cobble, etc.) or fill. The majority of these crossings (71 percent) were drilled through sand (i.e., sand, sand/clay, sand/silt, sand/gravel), 18 percent through fill, 18 percent through clay and silt, and 7 percent through other soil types (e.g., topsoil and marine deposits). Table 5 presents the soil types for inadvertent return events.

There was also a consistent offering of descriptions of "disturbed ground" near the site of the inadvertent return occurrence. More than 70 percent of inadvertent returns occurred in disturbed ground conditions, including those exhibiting pilings, tree roots, animal or crawfish burrows, fill, and previous HDD attempts. This high percentage indicates that inadvertent returns are more likely to occur where disturbed ground conditions are present.

Impact of inadvertent returns and remediation

The estimated volume of the reported inadvertent return releases ranged from less than 200 gallons and, in one incident, exceeded 84,000 gallons. However, further inquiry into the larger event indicated there was no attempt to mitigate the returns and the slurry was allowed to pool in a low area near the entry and exit pits. Disregarding the one large release of 84,000 gallons, the average total release was just over 2,200 gallons (or less than one vacuum truckload). Table 6 presents the estimated volumes of inadvertent returns and what, if any, containment or cleanup measures were implemented.

When containment was implemented, it was with normal methods of silt fence, hay bales, or earthen berms. After collection, the inadvertent return materials were either spread out on available upland right-of-way at the release site and mixed with native material or hauled offsite and disposed.

Containment/cleanup measures were not implemented at five of the 28 inadvertent return crossings. At three occurrences, no attempts were made to contain the inadvertent returns, although a significant volume of returns was realized at each occurrence (i.e., 8,400, 8,400, and 12,600 gallons). For these three events,

Table 6. Volume of return and containment/cleanup measures used

Crossing type	Estimated volume of return (gallons)	Containment measure	Cleanup/ Disposal activity
Roadway	84	Berm	Land farm
Bay	84	Hay bales	Manual
Bayou	100	Yes[1]	Yes[1]
Shore crossing	126	Berm	Backhoe
Bay	126	Hay bales	Manual
Unspecified	168	Silt fence	Manual
Shore approach	210	Berms	Vacuum truck
Lake	210	Silt fence	Manual
River	252	Berm	None[2]
Dry creek	400	Yes[1]	None
River	420	Silt fence	Backhoe
River	600	No[3]	None[3]
Creek	630	No	None
Shore approach	840	Silt fence	Vacuum truck
River	840	Silt fence	Manually
Creek	1,050	Silt fence	Land farm
River	1,260	Silt fence	Land farm
Creek	1,680	Silt fence	Land farm
Shore approach	2,100	Silt fence	Backhoe, pump
Creek	2,100	Berms	Pump, land farm
Creek	2,100	Silt fence	Land farm
River	2,520	Silt fence	Land farm
River	4,200	Silt fence	Land farm on ROW
Unspecified	8,400	None[4]	None[4]
Unspecified	8,400	None[4]	None[4]
Creek	8,400	Silt fences	Vacuum truck
Unspecified	12,600	None[4]	None[4]
Unspecified	84,000	Silt fence, berms	Vacuum truck

[1]Completed questionnaire did not specify type of containment or cleanup activity.

[2]River crested and washed away return before cleanup could be implemented.

[3]Return was dispersed by tide before cleanup could be implemented.

[4]As directed by regulatory agency.

the HDD contractors were directed by regulatory authorities not to implement containment or cleanup measures. It was thought that the impact of equipment and personnel to contain the inadvertent returns would cause a larger impact to the resource area than the release itself. For the other two inadvertent return occurrences, cleanup measures were not implemented before the inadvertent returns were naturally dispersed. In these instances, dispersal occurred via incoming tides and a cresting river.

CONCLUSIONS & RECOMMENDATIONS

The task of this research program involved assimilating data detailing large (i.e., greater than 750 feet long) HDD installations and any inadvertent returns that occurred. Information on these crossings was gathered by questionnaires sent to 11 HDD contractors. Over 50 completed questionnaires were returned.

Conclusions

Based on the data from these questionnaires and the findings of this Topical Report, the following conclusions can be made:

- Inadvertent returns occur during all stages of drilling; however, the most frequent occurrences are during pilot hole drilling and subsequent stages or during just the pre-reaming stages. Very few inadvertent returns occurred during the pullback stage only;
- Inadvertent returns occur most frequently within 200 feet of either the entry or exit hole, with a depth of cover less than 40 feet, and in granular soil;
- Disturbed ground along the drill path increases the occurrence of inadvertent returns, especially within the proximity of entry and exit pits. Examples of disturbed ground include tree roots, pilings, burrows, fill, and previous HDD attempts;
- Inadvertent returns occur most frequently during creek/river crossings and shore approaches, which represent more than 40 percent of all crossings;
- Inadvertent returns are more frequent at crossings with diameters of 22 inches or more;
- No correlation was found between the lack of normal returns and the occurrence of inadvertent returns;
- No correlation was found between slurry viscosity and pumping rates and an increased likelihood of inadvertent returns; and
- Increased length of crossing appears to influence the frequency of inadvertent returns slightly.

Recommendations

Inadvertent returns occur frequently enough during HDD installations that this phenomenon cannot be ignored. As mentioned above, most instances of inadvertent returns occur within 200 feet of the entry/exit pits, and increased depth of cover reduces the chances of inadvertent returns. Most instances of inadvertent returns produce manageable amounts of material that can be contained and disposed of without interrupting the construction operations, but may have at least temporary impacts on the associated resource area.

Based on the findings of this Topical Report, the following specific recommendations should be considered in the planning and execution of an HDD installation:

1. A geotechnical investigation should be conducted to determine prevalent soil types and the refine the drill profile prior to construction;
2. A site investigation should be conducted to identify disturbed ground such as pilings, and tree roots. These areas should be avoided or the depth of cover at these areas should be increased, if possible;

3. Although few crossings require redrilling due to inadvertent returns, many experience delays as a result of being unprepared for containment and clean-up of inadvertent returns. To minimize delays, contingency containment and clean-up plans should be in-place for every crossing. In most instances, containment is effective with silt curtains and hay bales, although plywood sheets often prove effective for deeper returns;
4. Construction right-of-way and access should be obtained for remedial operations in the first and last 200 feet of any HDD alignment; and
5. Slurry viscosity and pumping rates have no discernable affect on the likelihood of inadvertent returns so the HDD operation should not be compromised with instruction by a regulatory agency to lower rates.

REFERENCES

GRI. 1998. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: Literature Survey. Topical Report prepared by ENSR for the Gas Research Institute. GRI-98/0190. October.

GRI. 1999a. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: *Professional Screening Survey/Permit Condition Review*. Prepared by ENSR for the Gas Research Institute. Topical Report GRI-98/0350.

GRI. 1999b. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: Permit Condition and Mitigation Measures Review and Alternatives Evaluation. Topical Report prepared by ENSR for the Gas Research Institute. GRI-99/0132. September.

GRI. 2000a. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: Field Investigations. Topical Report prepared by ENSR for the Gas Research Institute. GRI-99/0236. April.

GRI. 2000b. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: A Comparative Assessment. Topical Report prepared by J.D. Hair & Associates, Inc. and ENSR for the Gas Research Institute. GRI-00/0046. December.

Stahelie, K., D. Bennett, and T.J. Hurley. 1998. Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling. Construction Productivity Advancement Research Program Technical Report CPAR-GL-98-1. U.S. Army Corps of Engineers, Waterways Experiment Station. April.

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Deep Compaction Resulting from Pipeline Construction – Potential Causes and Solutions

Troy T. Meinke, Tad L. Wesley, and Dean E. Wesley

Alliance Pipeline L.P. (Alliance) constructed its pipeline facilities in 1999 and 2000 through highly productive agricultural regions in the Midwest. Although Alliance's right-of-way reclamation was largely successful, selected land tracts on the construction right-of-way were observed to have reclamation problems that reduced crop yields as compared to cropland adjacent to the construction right-of-way, as well as compared to the construction right-of-way on other land tracts. Common problems observed on the right-of-way included ponded water, soil saturation, and stunted crops. As a result of reclamation research review and consultation with reclamation experts, Alliance identified soil compaction as a potential primary cause of reduced crop productivity in certain geographic areas. An applied field study was conducted to evaluate soil strength (a measure of compaction) in areas exhibiting symptoms of compaction. Most evaluated tracts had deep soil compaction (>10 inches deep) on the construction right-of-way as compared to measurements off right-of-way. Ripping was conducted to a minimum depth of 20 inches on tracts with deep compaction in an attempt to alleviate soil compaction and to improve crop yields. Results of the study indicate that ripping largely reduced soil compaction. However, crop yield responses to ripping varied by crop species. Soybeans did not show a consistent yield response, while corn yields consistently increased after ripping. This difference in crop response is likely a result of differences between the species in root structure and rooting depth. Potential causes of deep compaction were also evaluated as part of this study. Axle loads of construction equipment were found to be a potential cause of deep soil compaction. Soil moisture was also evaluated as a potential cause of deep soil compaction. High soil moisture content would have made soils more susceptible to deep compaction from construction traffic (Soehne, 1958). Above normal rainfall occurred in most of the study areas during construction, which contributed to the soil profile's susceptibility to deep compaction.

Keywords: Construction, restoration, reclamation, compaction, soil, pipeline, ripping, subsoiling, agriculture, crop yield

SOIL PROTECTION DURING THE ALLIANCE PIPELINE PROJECT

Construction of interstate natural gas pipelines is regulated by the Federal Energy Regulatory Commission (FERC), which has specific environmental requirements for all phases of construction. Pipeline construction has the potential to impact soils in several ways, including the following:

- compaction;
- topsoil and subsoil mixing;
- disruption of surface and subsurface drainage systems; and
- soil loss through water or wind erosion.

The Alliance Pipeline System (Alliance System) was constructed in 1999 and 2000 to transport high-pressure natural gas from the Western Canadian Sedimentary Basin to Chicago, where the Alliance System interconnects with the United States (US) pipeline grid (Fig. 1). Highly productive agricultural regions in the Midwest are crossed by the US pipeline route, including portions of North Dakota, Minnesota, Iowa, and Illinois. The Alliance Pipeline L.P. (Alliance) in the

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J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

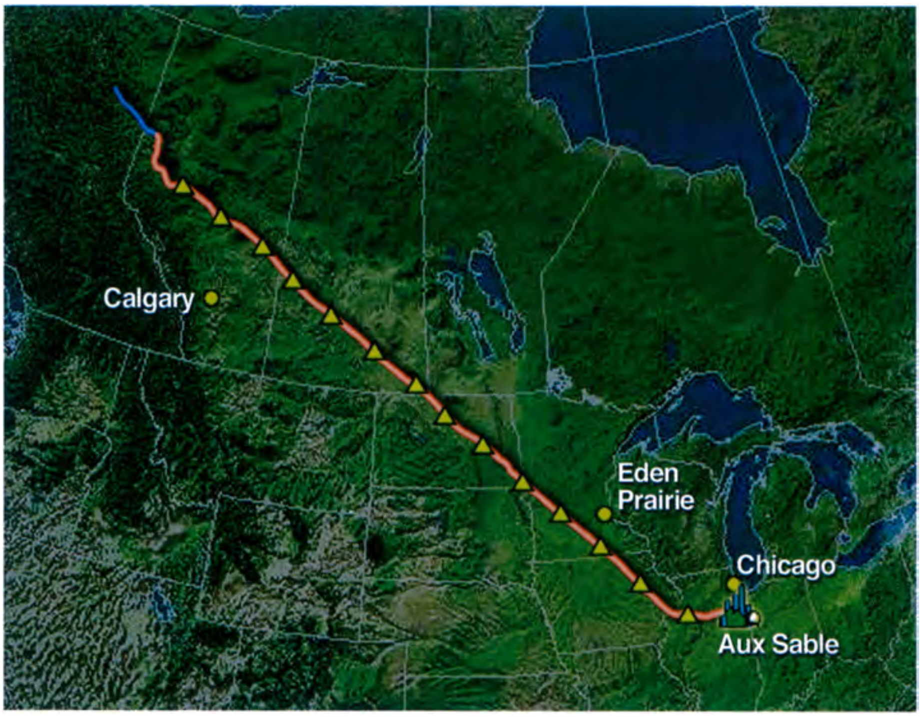

Fig. 1. The Alliance Pipeline System.

US consists of 888 miles of 36-inch diameter pipeline, ranging from 42 to 60 inches for specified depth of cover. The typical process for construction of large-scale pipeline projects was used during the construction of Alliance, which includes the following:

1. Staking, grading, and clearing: the boundaries of the right-of-way are identified and staked, followed by grading and clearing to create a smooth equipment travel lane without abrupt changes in topography;
2. Trench excavation: excavation of the trench is conducted for belowground placement of the pipeline to the required depth of cover;
3. Pipe stringing: semi-trucks or other means of transport move pipe joints from the pipe storage yard to the construction right-of-way for pipeline assembly;
4. Pipeline assembly: pipe joints are field bent as necessary, lined up, welded, and coated to form a contiguous pipeline;
5. Pipeline lowering: the assembled pipeline is lowered into the excavated trench;
6. Backfilling: backfill material, typically from the excavated trench, is placed over the lowered pipeline; subsoil materials are backfilled into the excavated trench first, followed by topsoil; and
7. Cleanup and restoration: debris and trash is removed, and the right-of-way is graded as near as practical to preconstruction contours and protected by implementing erosion control measures, which may include permanent slope breakers, reseeding, and/or mulch.

A cross-section of Alliance's typical construction right-of-way consists of topsoil and trench spoil storage areas, the excavated trench, and the working side of the right-of-way, which includes enough space for a working lane and a passing lane (Fig. 2). Typical construction right-of-way widths varied from 105 to 115 feet, depending on the pipeline depth of cover. More depth of cover over the pipeline requires a deeper trench, a larger spoil storage area, and a wider construction right-of-way.

Alliance committed to and implemented a large number of environmental practices and procedures to minimize the impact on soils during construction of its facilities. The FERC has prepared their Upland Erosion Control, Revegetation, and Maintenance Plan (Plan) for use during pipeline construction. Alliance also entered into Agricultural Impact Mitigation Agreements (Agreements) with each state crossed by its facilities as part of Alliance's commitment to proper stewardship of agricultural land. Table 1 below contains a general list of the soil protection measures addressed by the Plan and each of the Agreements.

POST-CONSTRUCTION RESTORATION ISSUES

Alliance initiated a five-year post-construction monitoring program to evaluate revegetation and crop productivity after the completion of construction. Although Alliance's right-of-way restoration is largely successful, some areas were observed to have crop yield reductions greater than expected, as compared to cropland adjacent to the right-of-way and cropland on Alliance's right-of-way on other tracts.

Common problematic symptoms observed on the right-of-way included ponded water, soil saturation,

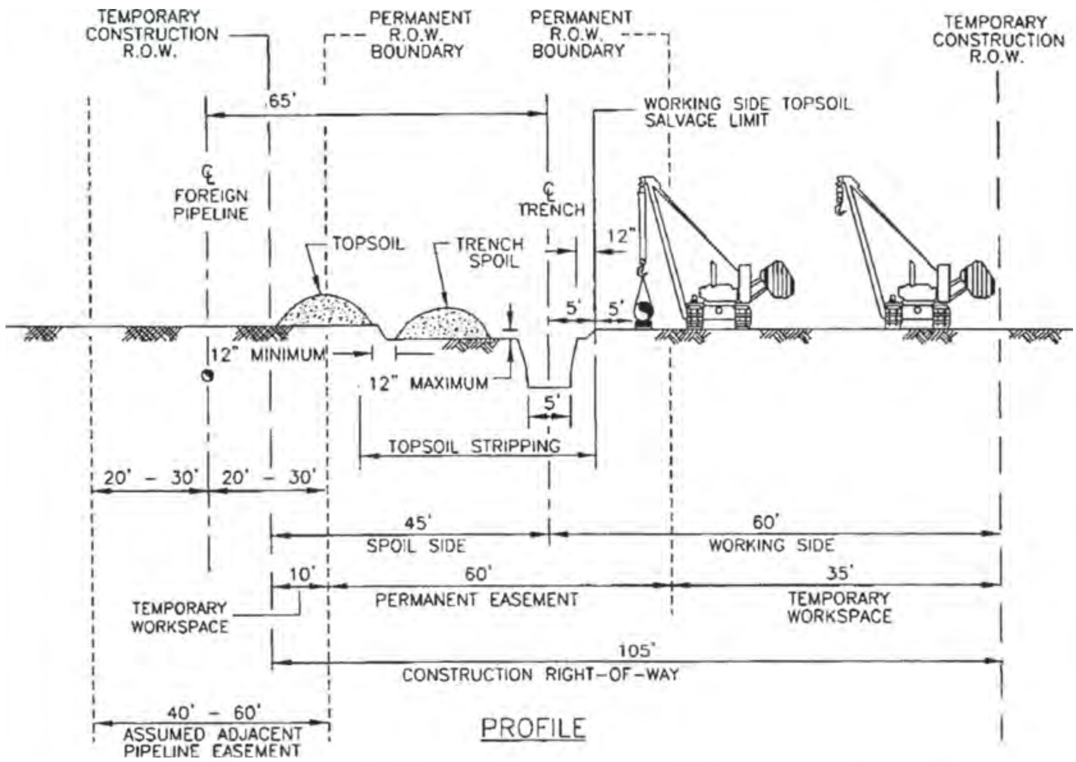

Fig. 2. Typical construction right-of-way configuration for the Alliance Pipeline Project.

Table 1. Soil protection measures – Alliance Agricultural Impact Mitigation Agreements and FERC Upland Erosion Control, Revegetation, and Maintenance Plan

Issue	FERC plan	North Dakota AIMA	Minnesota AIMA	Iowa AIMA	Illinois AIMA
Topsoil Replacement	✓	✓	✓	✓	✓
Drain Tile Repair	✓		✓	✓	✓
Rock & Debris Removal	✓	✓	✓	✓	✓
Compaction and Rutting	✓	✓	✓	✓	✓
Fertilization – Soil Restoration	✓	✓	✓	✓	✓
Soil Erosion	✓	✓	✓	✓	✓
Land Leveling	✓		✓	✓	✓
Conservation Practices	✓	✓	✓	✓	✓
Dewatering	✓	✓	✓	✓	✓
Wet Condition Construction			✓	✓	
Irrigation System Interference	✓	✓	✓	✓	✓
Soil-borne Pests and Pathogens		✓			

and stunted crops. Most of these symptoms were localized and were related to drain tile failures on the construction right-of-way, which were corrected with standard drain tile repair procedures. Several land tracts, however, exhibited soil saturation and crop stunting across the right-of-way. These symptoms were not related to drain tile failures and could not be resolved by repairing drain tiles. Alliance consulted with professional agronomists and reviewed available literature to identify potential soil properties that could cause the observed problems on the right-of-way. The expert review and literature search identified soil compaction as a potential cause of soil saturation and crop stunting.

Post-construction compaction of soils was not expected to be a significant concern on Alliance's right-of-way, because three passes of ripping had been specified to a depth of 18 inches to alleviate compaction on the construction right-of-way after final cleanup. In addition, environmental inspectors used hand-held soil penetrometers to conduct relative comparisons of soil compaction on and off the right-of-way after ripping. Tracts that remained compacted after three initial passes were ripped again to alleviate the remaining compaction, as measured by the environmental inspector's hand-held soil penetrometer. This ripping and penetrometer practice; however, could not measure and alleviate deep compaction (>10 inches deep) in the soil profile.

Alliance initiated a field study in 2002 to evaluate whether soil compaction remained on tracts exhibiting significant soil saturation and crop stunting.

Pending the findings of the compaction study, deep ripping (>20 inches deep) of tracts with significant compaction was planned to evaluate the effectiveness of ripping for compaction alleviation and to improve crop yields.

SOIL COMPACTION LITERATURE REVIEW

Soil compaction that results from equipment traffic and the moving and placement of soil materials will alter the physical properties of soil and is a major factor in post construction crop performance (Jansen et al., 1985). Increases in axle weight and soil moisture have also been shown to increase the depth and severity of compaction in the soil profile (Soehne, 1958). A compacted soil has poor aeration, low nutrient and water availability, slow permeability, and mechanical impedance to root growth (Raney et al., 1955).

In reconstructed mine soils, poor physical condition has proven to be the most severe and difficult limiting factor in the reclamation of prime farmland soils (Fehrenbacher et al., 1982). The root system is severely inhibited by excessively high soil strength of the compacted soil (Thompson et al., 1987; Meyer, 1983). Vance et al. (1998) found soil strength (compaction), measured with a cone penetrometer, to be highly correlated to corn yields and soybean yields. The response is curvilinear with yield decreasing as soil strength increases. At the upper limit, somewhere near 300 pounds per square inch (psi), any further increase in soil strength has minimal yield effects.

Corn plant growth and yield can be increased by using deep tillage on compacted reclaimed surface mine soils (Bledsoe et al., 1992). Studies reported by Dunker et al. (1992) also found corn yield increased with increasing tillage depth (Dunker et al., 1992). Increased yields were also reported for cereal, corn, and soybean crops in the growing season after subsoiling (ripping) treatments on pipeline rights-of-way (Mackintosh et al., 2000).

Successful restoration of crop productivity is dependent on soil management following the completion of construction. Research in Illinois shows that mine land productivity can be achieved if reclamation plans are designed to minimize compaction, use good quality soil materials, and use high management levels (herbicides, fertility, and adapted varieties) in rowcrop production (Dunker et al., 1998).

COMPACTION STUDY

A compaction study was initiated in the spring of 2002 to evaluate the compaction levels on tracts exhibiting symptoms of soil compaction. Soil strength, measured in psi, estimates the compaction level of a soil. A constant rate cone penetrometer was used to measure soil strength in the spring of 2002 on tracts in Illinois, Iowa and Minnesota, and in the spring of 2003 on tracts in North Dakota (Fig. 3). Soil strength measurements were taken in the spring of each year to minimize variability in the moisture content of the soil profile. Soil moisture typically is at or near field capacity in the spring. Measurements were collected to a depth of 30 inches. Data were collected directly over the pipe, on the working side of the right-of-way, and in an unaffected area off right-of-way for each sample location (Fig. 4). Sample locations typically were replicated 3 times for each tract. Sample locations were reduced to two on small tracts.

Fig. 3. Constant rate cone penetrometer.

Data from the soil strength measurements were summarized for the 0–10, 10–20, and 20–30 inch soil depth ranges. Off right-of-way measurements were referenced as a baseline for soil strength comparisons. Most tillage equipment used in production agriculture is only effective to around 14 inches, so the 10–20 inch depth range was used to determine if deep ripping was necessary. Tracts with soil strengths greater than 300 psi on the working side of the right-of-way were selected to be ripped in an attempt to alleviate compaction and improve crop yields. Soil strength of 300 psi was selected because it has been determined

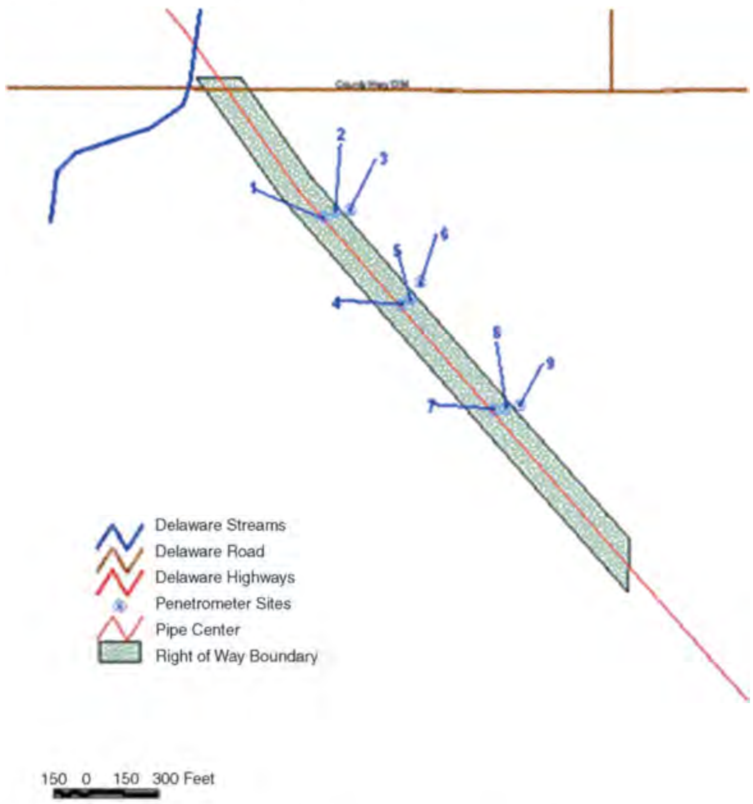

Fig. 4. Typical cone penetrometer sample locations.

to be the upper limit for yield loss responses due to compaction (Vance et al., 1998).

Tract ripping and follow-up compaction testing

A total of 27 tracts were ripped in the fall of 2002 that met the compaction criteria for this study. Tracts in Illinois were ripped using a DMI static-shank ripper to a depth of 30–35 inches (Figs. 5 and 6), and tracts in Iowa and Minnesota were ripped using a Koenig Enterprises DWK-500 ripper to a depth of 20–24 inches (Fig. 7). Ripping depths were dependent on the shank length of the ripper, which were 48 and 28 inches long, respectively. Also, ripping depths were restricted over the pipeline center to provide a safe distance between the ripping depth and the top of the pipeline. Tracts were ripped in the fall when soil moisture typically is low. A drier soil profile allows the soil to fracture more effectively, which improves compaction alleviation. One pass of the ripper was used for all deep ripping treatments. The soil was ripped through the topsoil into the subsoil layer. Follow-up soil strength measurements were collected on the Illinois, Iowa, and Minnesota tracts in the spring of 2003.

Sixteen tracts were ripped in fall 2003 to a depth of 30 to 35 inches in North Dakota using a Koenig Enterprises DWK-600 (Fig. 8). The DWK-600 ripper is similar to the DWK-500 ripper used in 2002, except that 37-inch shanks are used at 30-inch spacing, as compared to 28-inch shanks at 24-inch spacing. Tracts were ripped in the fall during low soil moisture conditions using a one-pass treatment. The soil was ripped through the topsoil into the subsoil layer. Tracts were not ripped directly over the pipeline centerline in North Dakota to avoid affecting the pipeline. Follow-up soil strength measurements were collected for these tracts in the spring of 2004.

Pre and post-ripping compaction analysis and results

A relative comparison was conducted between the pre and post-ripping soil strength measurements to evaluate the effectiveness of the ripping treatments. The comparison was limited to soil strengths in the 10–20 inch depth range, which reflects the effective ripping depth range consistently achieved during the study. Soil strength measurements from the working side of the right-of-way were used in this study, rather than an average of all right-of-way measurements. The working side data are a more consistent measurement of soil strength on the right-of-way, because ripping depths were restricted over the pipeline to provide a safe distance between the ripping depth and the top of the pipeline.

Soil strength was reduced in the 10–20 inch depth range on 33 out of 43 tracts (Fig. 9). Compaction at the 10–20 inch depth range was reduced more successfully on tracts ripped in 2002 as compared with tracts ripped in 2003. The soil strength after ripping was an average of 192 psi less than the soil strength measured before ripping in the 10–20 inch depth range on the working side of the right-of-way.

Fig. 5. DMI static-shank ripper.

Fig. 6. DMI static-shank ripper (tilling).

Post-ripping land management

Interviews were conducted with available landowners to identify land management practices that were implemented following deep ripping. Alliance cautioned landowners not to till the right-of-way in the fall after ripping, and to use the minimal tillage required to complete crop planting and fertilization the following spring. The purpose of this recommendation was to avoid recompaction of the fragile ripped soils. Some landowners did not follow Alliance's recommenda-

Fig. 7. Koenig DWK-500 ripper (tilling).

Fig. 8. Koenig DWK-600 ripper.

tions and created additional traffic on the right-of-way for tillage passes and fertilizer applications conducted only on the right-of-way and not on the rest of the tract.

Landowner interviews were available for 23 of the ripped tracts. Ten of the interviewed landowners reported that they had created additional traffic on the right-of-way for tillage passes and/or manure applications. The remaining 13 landowners conducted only normal traffic across the right-of-way associated with spring planting of the entire field. A review of the compaction data for these tracts indicates that extra traffic on the right-of-way partially or completely recompacted the ripped soils on the right-of-way in most cases (Fig. 10). Compaction was increased, or reduced less than 100 psi on 8 out of 10 tracts that received extra traffic on the right-of-way. Conversely, 9 of the 13 tracts that had normal traffic on the right-of-way showed reductions of compaction greater than 100 psi. The three tracts with normal traffic that increased in compaction also showed an increase in compaction off right-of-way, which indicates that the farming practices on these tracts may have increased compaction on the entire field.

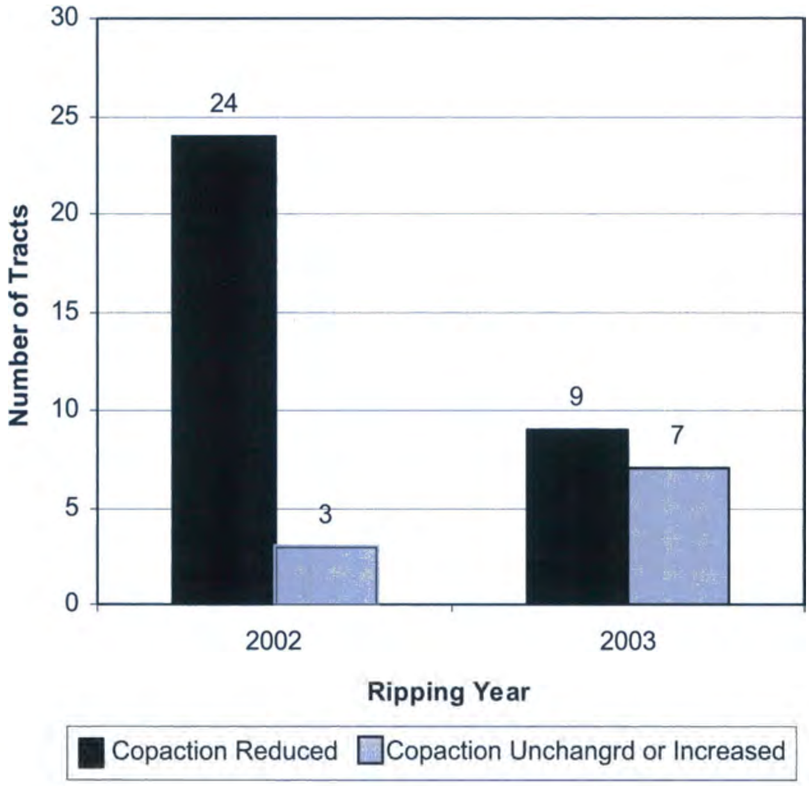

Fig. 9. Compaction level response to ripping in the 10–20 inch depth range.

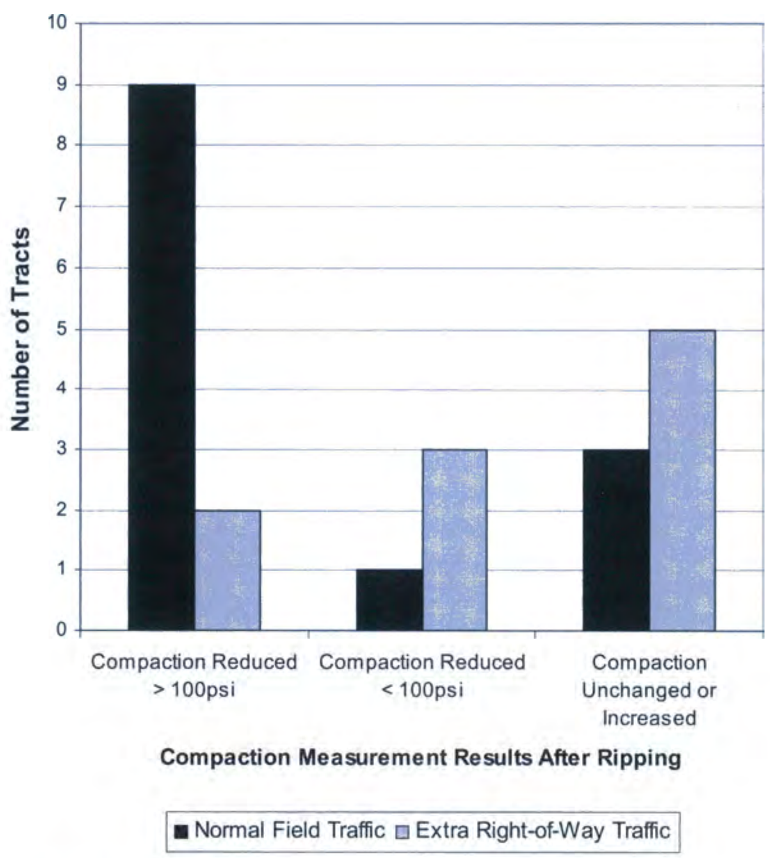

Fig. 10. Compaction reduction by ripping as affected by land management.

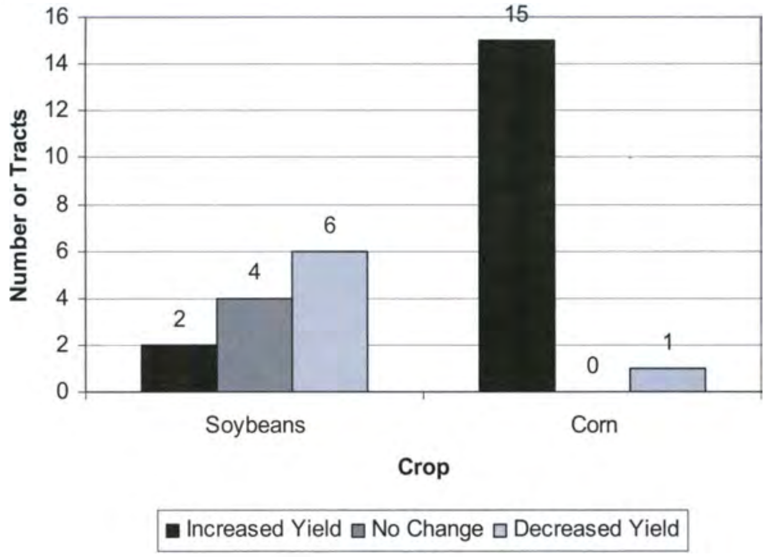

Fig. 11. Crop yield responses to ripping.

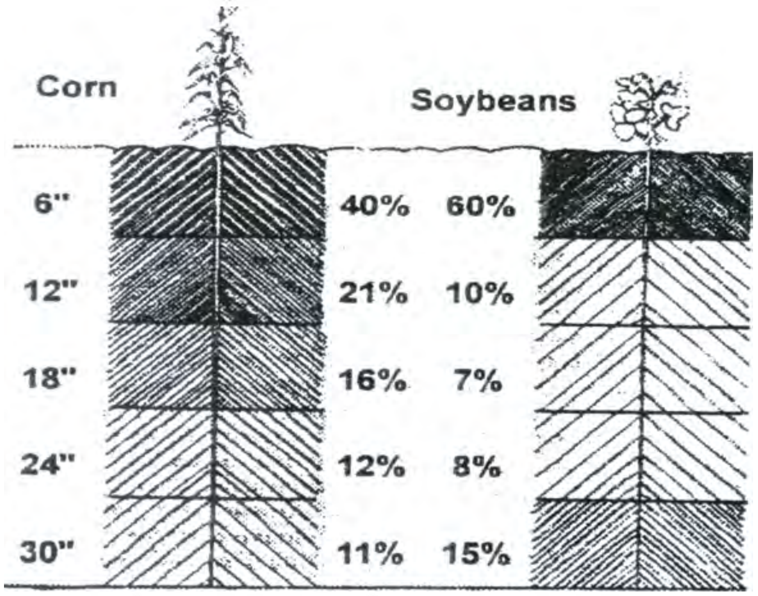

Fig. 12. Soybean and corn rooting depths (Lant, 2004).

CROP YIELD STUDY

Crop yield estimates were collected in late summer and early fall of 2001 through 2004 to assess yield responses on tracts ripped in 2002 and 2003. Crop yield evaluations were restricted to same-crop comparisons to avoid variability in responses between different crop species. Some tracts rotated crops in a manner that prevented a same-crop evaluation. As a result, only 28 tracts could be evaluated for yield response.

Yield estimates were quantified in bushels per acre on the working side of the right-of-way and off right-of-way. One sample per tract was acquired in 2001. Two samples were acquired and averaged per tract in 2002, 2003, and 2004. Samples were averaged to account for in-field variability. Working side yield responses were calculated as a percentage of baseline (off right-of-way) yield estimates.

A comparison between pre-ripping and post-ripping yield responses is shown in Fig. 11. Soybeans showed no consistent yield response to alleviation of deep compaction. One contributing factor to a lack of yield response in soybeans is that 60 percent of its root system typically is in the top six inches of the soil profile, which would not be adversely affected by compaction below ten inches in the soil profile (Fig. 12).

Corn showed an increased yield response from alleviation of deep compaction on 15 of 16 tracts (Fig. 11). Yields were improved an average of 17 percent as compared to off right-of-way yields. A yield increase of two

Fig. 13. Corn rooting depth in a ripped soil.

to three percent would be anticipated during normal field recovery after disturbance, based on Alliance's crop monitoring program, which was conducted during the same time frame as this study. Corn is expected to be more adversely affected by soil compaction in the 10–20 inch depth range than soybeans, because 60 percent of its rooting structure occurs below six inches of the soil profile (Fig. 12) (Lant, 2004). Increased corn yields are likely the result of more available water from a larger rooting volume that develops to a greater depth in the soil profile. A soil pit was excavated one year after ripping on a corn tract to evaluate rooting depth. Corn roots were observed at a depth of approximately 33 inches in the path of the shank in the soil profile (Fig. 13).

As plant roots extract water from the soil, they follow the cracks formed by the ripper, which causes the soil to shrink and form desiccation cracks. The desiccation cracks that form are available to conduct rainwater back into the dried soil profile and re-swell the soil. Roots will invade the cracks, extract more water, and the cycle will be repeated. Resulting wet–dry cycles will cause more cracks to form and in time contribute to alleviation of the soil compaction problem (Wesley et al., 1988).

An interview with the landowner on the corn tract with no yield response indicated that an extra tillage pass had been conducted on the right-of-way separate from the rest of the field, potentially contributing to recompaction and ongoing crop yield loss on the right-of-way. The soil strength in the 10–20 inch depth range of the soil profile remained consistent with the pre-ripping soil strength measurements, indicating that root growth was still being limited in the soil profile.

FACTORS AFFECTING SOIL COMPACTION DURING PIPELINE CONSTRUCTION

Axle load

Construction of modern pipelines involves the transporting and handling of heavy pipe. The standard pipe used to construct Alliance's mainline pipeline weighs approximately 235 pounds per linear foot. During construction, three 80-foot sections of pipe typically were transported to the right-of-way on a stringing truck, which equates to an approximate load of 28 tons. Stringing trucks typically are rubber-tired semis with a flatbed trailer, which are designed for highway use. Other heavy equipment is also required for pipeline construction, including excavators, pipelayers, and bulldozers. Research has shown that the depth and severity of compaction increases as axle loads increase on agricultural land (Soehne, 1958) (Fig. 14). This indicates that heavy equipment traffic on Alliance's construction right-of-way likely contributed to the occurrence of deep compaction on the tracts included in this study.

Soil moisture

Variable climate conditions were experienced during construction of the Alliance Pipeline over a two-year construction timeframe. The variable of most interest for soil compaction is the amount of rainfall received during the construction season, which is expected to directly influence soil moisture content. Soil moisture is a key factor in the susceptibility of soils to compaction. Research has shown that compaction from a static vehicle axle load penetrates deeper into the soil profile as soil moisture increases (Soehne, 1958) (Fig. 15). This is very pertinent to pipeline construction, given the heavy axle loads of tracked and rubber-tired equipment.

Data were compiled to evaluate the precipitation received during construction in the area of tracts included in this study. Environmental inspection reports were also reviewed to identify the timeframe of construction from grading through cleanup and restoration on each tract. The "construction season" includes the month preceding and the months during all construction activities. Precipitation data during the construction season was compared with the 30-year precipitation average for the same geographic location to evaluate whether the soil profile received greater

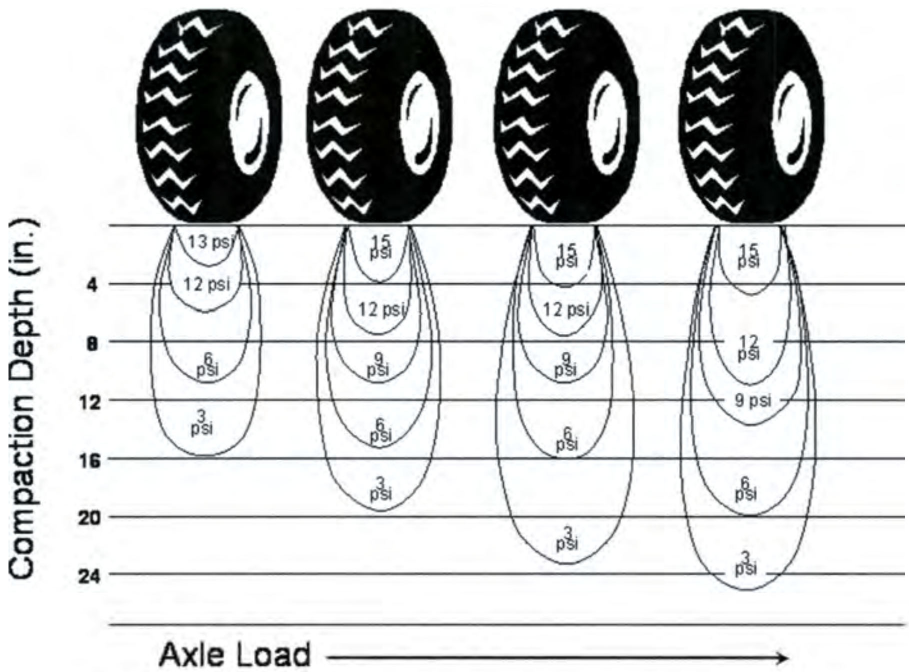

Fig. 14. Depth of compaction as axle loads increase (adapted from Soehne, 1958).

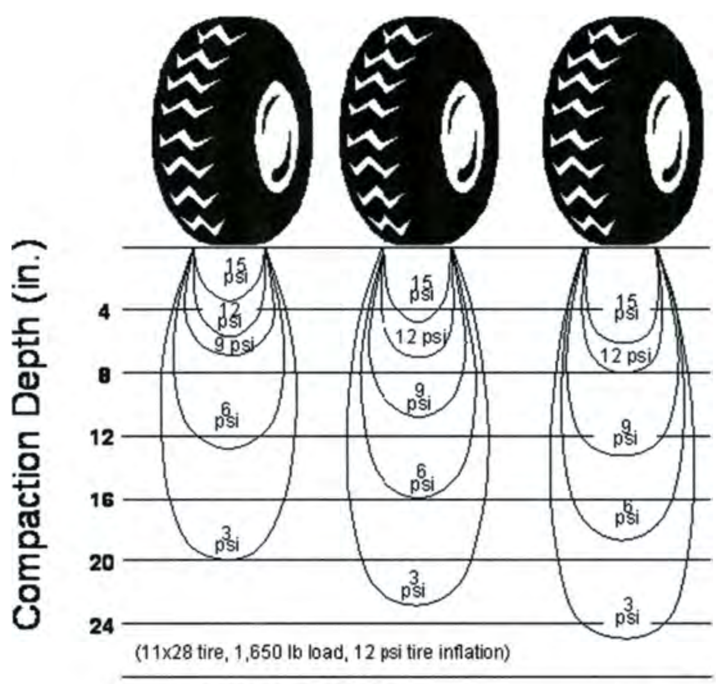

Fig. 15. Depth of compaction as soil moisture increases (adapted from Soehne, 1958).

than normal, normal, or below normal amounts of precipitation. The months with the greatest surplus of precipitation and the greatest deficit of precipitation, as compared to the 30-year average, were also identified within the construction season at each tract location. The results of this evaluation are listed in Fig. 16 below.

All of the tracts exhibiting deep soil compaction experienced normal to above normal precipitation during the construction season (Fig. 16). In addition, all but one geographic location received significant amounts of rain on a per-month basis, with many tracts receiving five or more inches of rain above the 30-year average in at least one month during the construction season. Tracts that receive greater amounts of precipitation just prior to and during the construction period are expected to also have a higher soil moisture content, which makes the soil profile more susceptible to

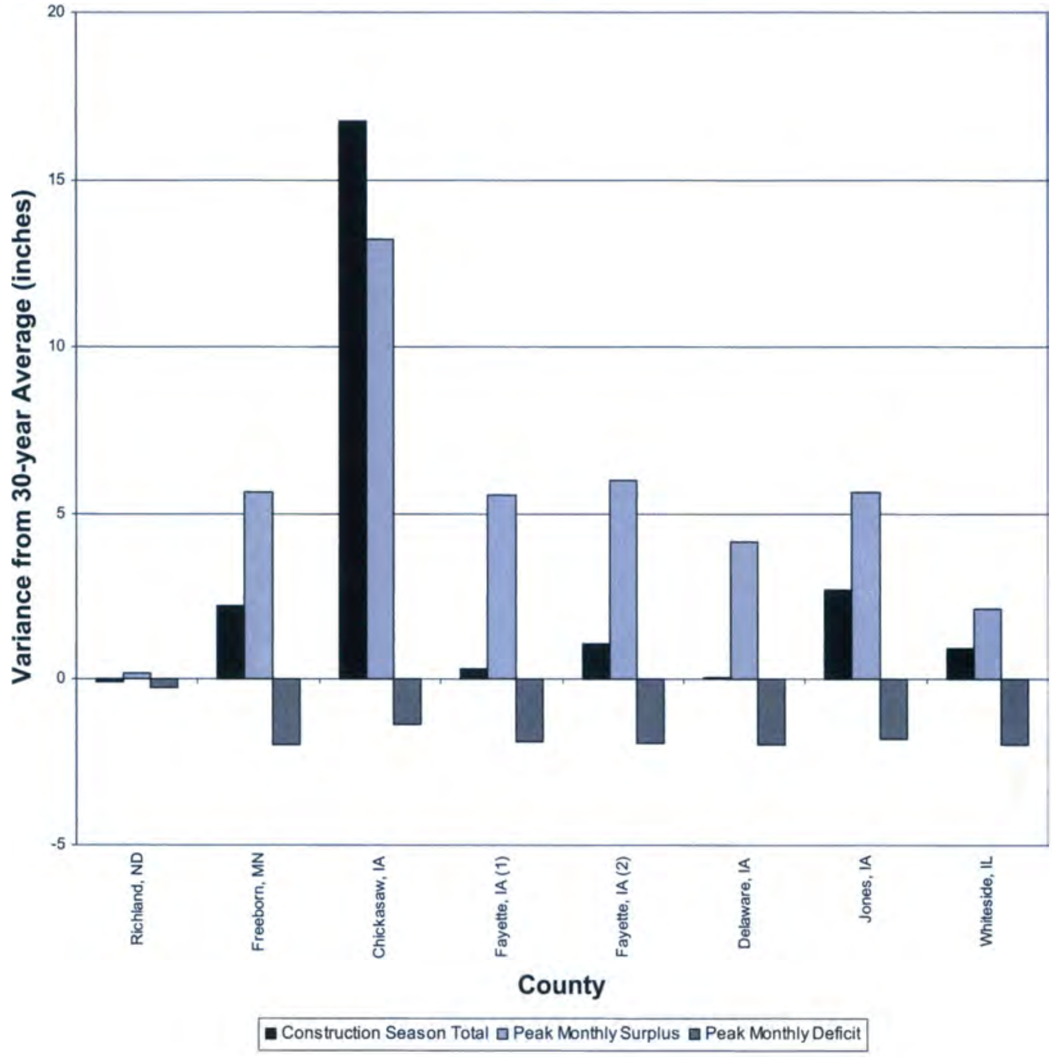

Fig. 16. Construction season precipitation variance from the 30-year norm.

deep soil compaction. High soil moisture content likely contributed to the occurrence of deep soil compaction during active construction at the tracts included in this study. Deep compaction would not have been alleviated during ripping conducted during the cleanup and restoration phase of construction. This ripping was effective to an approximate depth of 14 inches.

CONCLUSIONS

The results of this study indicate that pipeline construction activities, under certain mechanical and environmental conditions, can cause deep soil compaction in Midwestern agricultural soils. Deep soil compaction results in problematic soil conditions such as ponded water and high soil strength that leads to reduced crop yields.

Ripping soils to alleviate deep compaction was largely successful when fields were properly managed after ripping was completed. Standard post-construction ripping efforts are not expected to be adequate if deep compaction exists on the right-of-way, because these tillage operations are only effective to approximately 14 inches. Specialized rippers and high horsepower tractors are required to rip to depths that can effectively alleviate deep compaction.

Although ripping is effective at reducing deep soil compaction, this may not be the limiting factor for yield responses of some types of crops. Data from this study indicates that soybeans did not benefit from deep ripping. The lack of yield response by soybeans is likely caused by approximately 60 percent of its root system occurring in the top six inches of the soil horizon. Deep soil compaction would not restrict root growth in soybeans as much as other deeper rooting crops. Conversely, corn showed a positive response in all but one tract evaluated for yield response to ripping. Approximately 60 percent of corn root structure; however, occurs below six inches in the soil horizon. Past research has also shown corn yield increases in response to deep tillage.

Ripping was conducted using one pass on the right-of-way. Further study should be considered to assess whether additional passes of ripping would further reduce soil strengths and increase crop yield responses. In addition, little is known about the effectiveness of different ripping practices, including ripping the subsoil in areas stripped of topsoil before the topsoil is replaced.

Further study is also needed to assess whether ripping provides long-term compaction alleviation and positive crop yield response on pipeline rights-of-way. It is not possible to reliably assign a long-term percentage of yield response to compaction alleviation without a high level of land management control after ripping. The most effective time to implement ripping in pipeline construction may be immediately after construction, when pipeline companies typically have committed damage payments to landowners and have the opportunity to negotiate specific post-construction land management plans for one to several years.

RECOMMENDATIONS

Avoidance of activities prone to causing compaction during construction is the best way to avoid the problematic symptoms of deep compaction. Alternative construction practices, when practical, can be used to minimize the potential for deep compaction. Examples of alternative practices include the following:

1. String the pipe on the right-of-way using the trench centerline as the stringing road before trench excavation is conducted (Mackintosh et al., 2000). This practice avoids compaction that typically occurs on the working side during stringing. Compaction on the trenchline will also be alleviated as the trench is excavated for placement of the pipeline;
2. Overall traffic minimization during construction and the use of low ground pressure equipment, when possible, will reduce the frequency and severity of axle loads on the right-of-way, subsequently minimizing compaction; and
3. Wet weather shutdowns avoid construction traffic when soils are most susceptible to deep compaction. However, this practice is often impractical, given the time sensitivity of typical pipeline construction.

Ripping can be used as a tool to alleviate deep compaction. However, specific ripping practices and post-ripping land management are key factors to maximize the benefits of ripping. The following practices were found to be important to maximize the benefit of ripping:

1. Rip soils to an adequate depth to alleviate compaction. Compaction in the 0–10 inch depth range of the soil profile is typically alleviated by standard rippers, which effectively alleviate compaction up to approximately 14 inches in depth. Deep compaction, however, requires tillage using a larger ripper with a tractor of sufficient horsepower to fracture the soils below the depth of compaction in the soil horizon;
2. Conduct ripping under low soil moisture conditions. The soil profile should be relatively dry during ripping to enhance the fracture of compacted soils. Wet soils may actually be further damaged by ripping; ripping in wet soils is like pulling a knife through butter, which can cause additional compaction at the shank-to-soil interface; and
3. Prepare and implement a post-ripping land management plan with the landowner or land manager. Land management plans should specify minimal equipment traffic on ripped soils. These plans could also include additional reclamation practices, such as planting of alfalfa or other deep-rooting, perennial species for a specified number of growing seasons to stabilize ripped soils and to improve soil structure.

While ripping shows promise as a method to reduce compaction and improve crop yields after pipeline construction, it should not be considered a "cure all" for deep compaction issues related to pipeline construction. Ripping should be used instead as a tool in an overall pipeline right-of-way construction and restoration program.

ACKNOWLEDGEMENTS

The authors wish to thank the employee-partners of Alliance Pipeline L.P. for providing the support, resources, and operational philosophy that made this study possible. Thanks are also extended to the landowners that were willing to work with us in an effort to learn more about pipeline construction reclamation.

REFERENCES

Bledsoe, L., E.C. Varsa, S.K. Chong, F.J. Olsen, B.P. Klubek, and D.J. Stucky. 1992. The Effects of Deep Tillage of Reclaimed Mine Soils on Corn Root Development. pp. 51–58. Dunker, R.E., R.I. Barnhisel, and R.G. Darmody (Eds.). Proceedings of the 1992 National Symposium on Prime Farmland Reclamation. Department of Agronomy, University of Illinois, Urbana, Illinois 61801.

Dunker, R.E., C.L. Hooks, and R.G. Darmody. 1998. Effect of Reclamation Method on Mine Soil Productivity in Illinois. pp. 67–74. Hooks, C.L., Kimery C. Vories, and Dianne Throgmorton (Eds.). Proceedings of Prime Farmland Interactive Forum. University of Southern Indiana at Evansville. March 3 & 4, 1998.

Dunker, R.E., C.L. Hooks, S.L. Vance, and R.G. Darmody. 1992. Effects of Deep Tillage on Surfaced Mined Land in Southern Illinois. pp. 59–69. Dunker, R.E., R.I.Barnhisel, and R.G. Darmody (Eds.). Proceedings of the 1992 National Symposium on Prime Farmland Reclamation. Department of Agronomy, University of Illinois, Urbana, Illinois 61801.

Fehrenbacher, D.J., I.J. Jansen, and J.B. Fehrenbacher. 1982. Corn root development in constructed soils on surface-mined land in western Illinois. Soil Sci. Soc. Am. J. 46: 353–359.

Jansen, I.J., R.E. Dunker, C.W. Boast, and C.L. Hooks. 1985. Row crop response to soil horizon replacement. Symposium on the Reclamation of lands Disturbed by Surface Mining: A Cornerstone for Communications and Understanding. Science Reviews Limited, Middlesex, England pp. 410–430.

Lant, C. 2004. An Ideal Root System on a Corn Plant. Walking Your Fields. Pioneer Hi-Bred International, Inc., Johnston, IA. May 24, 2004.

Mackintosh, E.E., E.J. Mozuraitis, and R.C. Rowland. 2000. The Union Gas Crop Yield Monitoring Program: An Evaluation of Pipeline Construction Practices on Agricultural Lands. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management at Calgary, Alberta, Canada, September 9–13, 2000.

Meyer, J.J. 1983. Corn root behavior in soils constructed after surface mining for coal in southern Illinois. Unpubl. M.S. Thesis. University of Illinois, Urbana, IL 61801.

Raney, W.A., T.W. Edminster, and W.H. Allaway. 1955. Current status of research on soil compaction. Soil Sci. Soc. Am. Proc. 19: 423–428.

Soehne, W. 1958. Fundamentals of pressure distribution and soil compaction under tractor tires.1958. Agricultural Engineering, St. Joseph, MI, pp. 276–290.

Thompson, P.J., I.J. Jansen, and C.L. Hooks. 1987. Penetrometer resistance and bulk density as parameters for predicting root system performance in mine soils. Soil Sci. Soc. Am. J. 51: 1288–1293.

Vance, S.L., R.E. Dunker, C.L. Hooks, and R.G. Darmody. 1998. Relationship of Soil Strength and Rowcrop Yields on Reconstructed Surface Mine Soils. pp. 35–42. Dunker, R.E., R.I.Barnhisel, and R.G. Darmody (Eds.). Proceedings of the 1992 National Symposium on Prime Farmland Reclamation. Department of Agronomy, University of Illinois, Urbana, Illinois 61801.

Wesley, D.E., K.A. Wesley, P.L. Christy. 1988. Effect of Crop Sequence on Root Penetration and Bulk Density in Reclaimed Strip Mined Land. Abstract, 16th Annual Conference of the National Association of State Land Reclamationists. LaSalle, IL. September 14, 1988.

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Effects of Heat from a Pipeline on Crop Growth – Interim Results

Gordon Dunn, Lorne Carlson, Gina Fryer, and Melissa Pockar

Few published studies have previously addressed the effects of heat from pipelines on crop growth. Consequently, Alliance commissioned a study in 2002 to assess pipeline heat effects on soil temperature and crop growth along the Alliance 36″ pipeline in central Alberta. The study was designed to assess soil heating effects on crop growth, as well as the distance downstream from compressor stations that soil heating effects are encountered. Five locations were selected at varying distances downstream of compressor stations. Plant establishment and productivity, as well as soil moisture and temperature, were monitored to assess the influence of heating on crop production and soil properties. At each location, plant growth and soil moisture parameters were collected from replicated square meter plots along three transects within each site. Germination and seedling emergence data was collected at the beginning of the season. Soil samples for moisture analysis were collected monthly throughout the growing season. At maturity, square meter samples were harvested for yield analysis. The study was conducted over a three year period from 2002 to 2004. Preliminary results indicate that heat from the Alliance pipeline is measurable in the top 60 cm of soil over the pipeline for a distance of 190 km downstream of compressor stations. No effects of soil heating were found on plant available water in the rooting zone or on yield of annual crops.

Keywords: Soil temperature, soil heating, pipeline, soil moisture, crop growth

INTRODUCTION

In 1998, Alliance Pipeline Ltd. (Alliance) received approval from the National Energy Board (NEB) to construct the Canadian portion of a natural gas pipeline system to transport gas from northeast British Columbia and western Alberta to a hub near Chicago, USA. Pursuant to a condition of the approval, Alliance was required to monitor heat effects on crop growth and vegetation downstream of mainline compressor stations.

The main trunk line of the Canadian portion is approximately 1565 km (970 mi) in length and has an outside diameter of 914 mm to 1,067 mm (36 to 42 in). Compressor stations are located at approximately 193 km (120 mi) intervals along the majority of the Canadian mainline. Heat from compression of natural gas at compressor stations results in a temperature gradient along the pipeline typically ranging from approximately 40 C (105 F) at the outlet of a compressor to 16 C (60 F) at the inlet side of the next compressor. Some landowners have expressed concerns regarding the potential effects on soil temperature and crop growth resulting from the heating of soil above the Alliance pipeline.

TERA Environmental Consultants (TERA) was commissioned by Alliance to conduct a post-construction soil heating study along the Canadian portion of its natural gas pipeline system. The objectives of the study are to characterize the nature of soil heating caused by the pipeline and investigate the associated effects on crop growth. Crop productivity, as well as soil water and temperature, were monitored during the 2002, 2003 and 2004 growing seasons at five locations at varying distances from compressor stations. Since data from the 2004 season has, to date, not been completely collected and analyzed, interim results of the study are presented in this paper. The primary focus of results

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presented are the measured relationship between soil heating and soil moisture content, as well as crop yield comparisons between the pipe centreline and adjacent off centreline areas of the right-of-way.

LITERATURE REVIEW

Few published studies have previously addressed the effects of heat from pipelines on crop growth. Heat from a buried pipeline may create a localized increase in soil temperature if the temperature of the pipeline exceeds that of the surrounding soil. Soil water is thought to migrate away from a hot pipe, possibly creating a dry core around the pipe. Heat from pipelines has been shown to heat surrounding soil, particularly immediately downstream of compressor stations (Naeth, 1985; Burgess and Smith, 2001).

Burgess and Smith (2001) looked at shallow ground temperatures in the Mackenzie valley. The Norman Wells to Zama, Alberta oil pipeline shows warming and ground subsidence associated with the clearing of the pipeline right-of-way. Cross sections showing the depth of thaw at the time of site establishment in the 1980s and ten years later in the 1990s show that thaw depths are greater in the vicinity of the buried pipe due to the warm pipe-operating temperatures, the increased level of terrain disturbance in the pipeline trench and that the trench backfill is frequently subsided and wetter than the adjacent right-of-way.

Naeth (1985) measured soil temperatures at five depths from 5–110 cm on the trench line of a 107 cm diameter gas pipeline and reported elevated soil temperatures as compared to off right-of-way control measurements. Temperatures at shallow depths were strongly affected by air temperature and differences from controls were likely due, to a large extent, to lack of vegetation over the pipeline. During the winter, heat effects from the pipeline were obvious at lower depths but not evident in the top 60 cm of the soil profile. During the summer, heat effects from the pipeline were minimal even at the lower depths. This was attributed to decreased gas flow through the line during the summer months. Pipeline construction and operation affect the soil thermal regime of the disturbed area by altering the soil texture, bulk density and water content and also by heat from the compressed gas flowing through the pipe (Naeth et al., 1993). Two fundamental soil thermal properties, thermal conductivity and heat capacity, are largely a factor of texture, bulk density, and soil water. An altered thermal regime affects the water regime. All these factors have the potential to affect plant growth.

Some studies have looked at how elevated soil temperatures affect crop growth. Among them, Kaspar and Bland (1992) found that as soil warming advances downward, progressively deeper soil layers become suitable for root growth. The depth of soil thermally suitable for appreciable root growth is a function of both soil temperature regime and root temperature response. McMichael and Burke (1998) found that relatively small changes in soil temperature can have significant impacts on the development of the root system in a wide variety of plants, depending on the stage of growth and the durations of the changes.

Stone et al. (1999) found that warm soil reduced the time to maize crop emergence by approximately 1 day for every 1 °C rise in average soil temperature at meristem depth. Because warm treated maize intercepted significantly more radiation than either the normal or cool treatments, grain yield tended to increase with soil temperature. McMaster et al. (2003) found that heating the soil resulted in significantly earlier spring wheat seedling emergence, regardless of planting date. However, even though the seedling emergence began sooner after planting when the soil was heated, the final number of seedlings that emerged was generally similar for all treatments in all years.

In a study of the effects of soil heating from underground power cable ducts in Ontario, Spencer (1975) showed that elevation of root zone temperature by 10–15 °C caused soil drying, which adversely affected the plant growth and yield of a number of crop species. Ketcheson (1970) demonstrated that heating soil to 22 °C (approximately 6 °C higher than control treatments) advanced the growth and development of corn plants in southern Ontario to an earlier maturity.

Soil temperature differences between pipeline trenches and undisturbed soil have been documented but are not entirely attributed to heat effects from buried pipelines. Stewart and Mackenzie (1979) reported elevated soil temperature over the trench line of an oil pipeline right-of-way. They attributed the higher temperatures to one or all of three factors: 1) changes in thermal diffusivity of the trench line soil caused by the physical disruption of trenching and backfilling; 2) changes in surface heat absorption properties due to differences in plant cover; and 3) heat transfer to the soil from the buried pipeline.

Increased soil temperatures and crop yields were observed over warm water pipelines (Rykbost et al., 1975a; 1975b). Underground, 35 °C water pipes increased the daily soil temperature at 5, 25 and 45 cm depths by 1.0, 4 and 6.5 °C, respectively, during the growing season. The small temperature increases were important during germination and early seedling growth. Soil warming reduced the time required for germination and increased subsequent seedling growth rate. The crops depleted the available soil water faster in the heated plots than in unheated plots. However, yield increases were observed for irrigated crops in that study.

The observations made in these studies highlight the complexity of interacting factors affecting the soil temperature over underground pipelines, and the difficulties involved in accurately characterizing the effects on plant growth from soil heating separately from plant growth effects from other pipeline related soil disturbances.

METHODS

Environmental factors

The study area lies within the Central Parkland Subregion of the Parkland Natural Region (Alberta Environmental Protection (AEP), 1998) (Fig. 1). The area is in the Black Chernozem Soil Zone with level to gently undulating topography (Alberta Agriculture Food and Rural Development, 2002). Most of the native vegetation in the project area has been cleared for agriculture. The most common crops grown in this area are annual cereals, canola and perennial pasture and forage crops. Average annual precipitation for the area is approximately 45 cm (18 in) with approximately half of this precipitation occurring as rainfall during the months of May to August (Holmes et al., 1976).

Fields within the study area suffered from drought conditions in 2002. Precipitation during the growing season was very low and, on average only 10 to 20 percent of season normals. Precipitation in 2003 was improved to the below normal to normal range. Precipitation in 2004 improved again from previous years with normal to above normal levels during the growing season.

Site selection

Five locations were selected along the Alliance pipeline. Site selection was based on landowner consent, land use, and distance from the compressor station. The intent was to keep region and soils as similar as possible between sites to minimize between site variability. One site is located upstream and four are located downstream of the Morinville Compressor Station (Fig. 2, Table 1). The area around Morinville, Alberta was selected for the soil heating study since it is typical of agricultural areas crossed by the Alliance Pipeline in western Canada. The sites are approximately 800 m upstream (Site 1), and 900 m (Site 2), 19 km (Site 3), 60 km (Site 4), and 84 km (Site 5) downstream of the Morinville Compressor Station. Gas temperatures are greatest immediately downstream from the compressor station; therefore, Site 2 was expected to experience the greatest soil temperature effects from

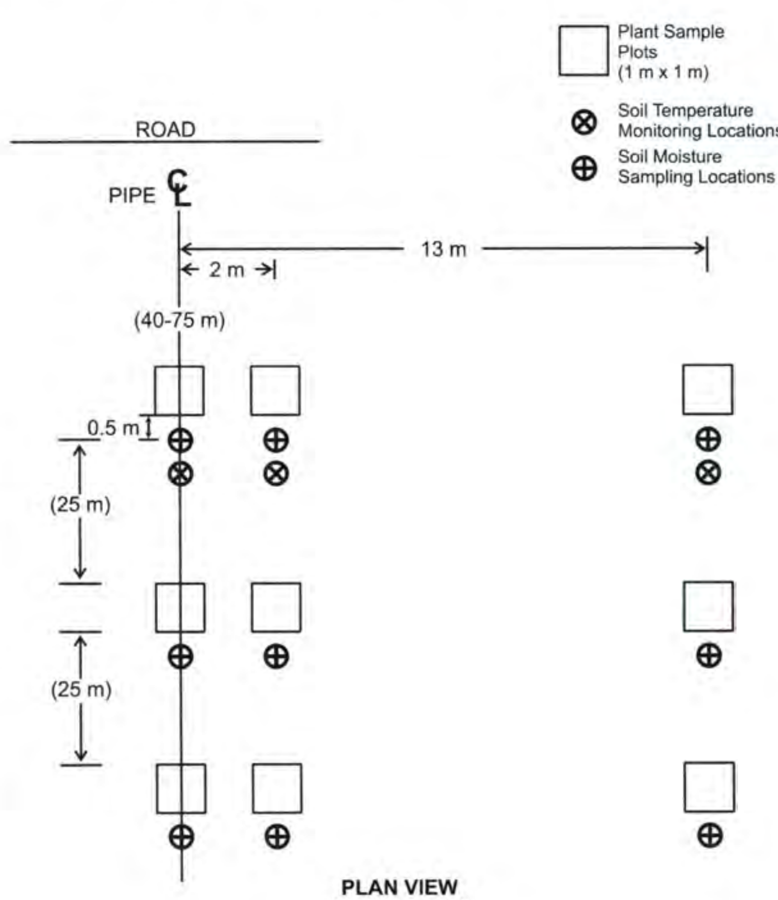

Fig. 1. Typical site layout.

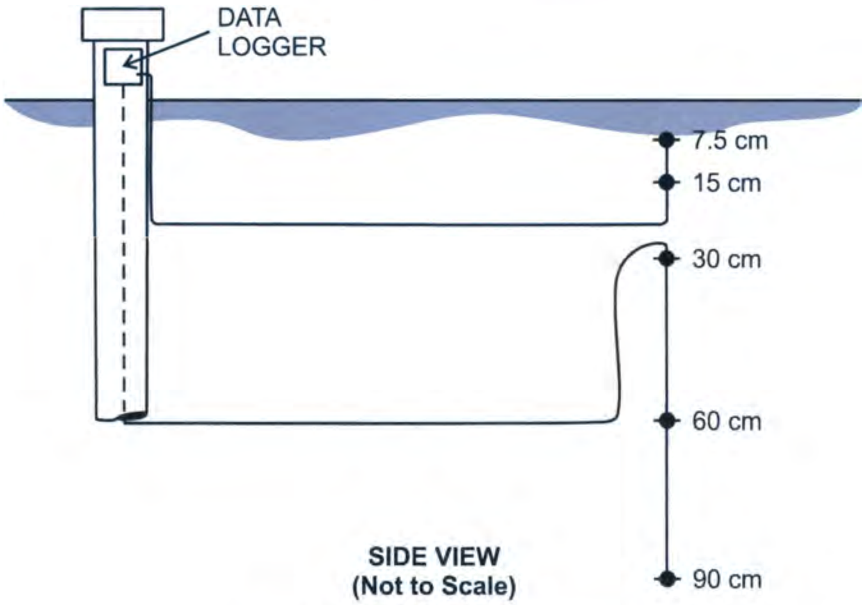

Fig. 2. Typical temperature soil probe layout.

Table 1. Year 2002 mean plant available soil water (%)

Sampling location	Depth in soil profile 0–15 cm	15–30 cm	30–60 cm	Location means
Centreline	3.84 ± 0.8 a	3.52 ± 0.7 a	2.27 ± 0.6 a	3.21 ± 0.4 a
2 m off centre	3.30 ± 0.8 a	2.80 ± 0.7 a	2.20 ± 0.6 a	2.77 ± 0.4 ab
13 m off centre	2.97 ± 0.7 a	2.21 ± 0.7 a	1.64 ± 0.8 a	2.27 ± 0.4 b

Note: Means within columns with the same letter are not significantly different ($p > 0.05$).

the pipeline, while Site 1, on the inlet side of the compressor station, was anticipated to experience the least effects on soil temperature.

Site layout

Plant growth parameters and soil samples were collected from square metre plots along three transects within each site (Dwg. No. 1). The transects were spaced approximately 25 m apart along the pipeline right-of-way. Within each transect, one plot was located directly over the pipe centreline, the second was 2 m off the centreline, and the third was located 13 m off the centerline. There were a total of nine sample plots (3 transects/site × 3 plots/transect) at each site.

Soil temperature

Soil temperatures were recorded with a datalogger and temperature probes were installed in three locations at each site (on centreline, 2 m off centreline and 13 m off centreline) at depths of 7.5, 15, 30, 60, and 90 cm (Dwg. No. 2). Temperatures were recorded continuously throughout the growing season at all sites.

Soil water

Soil samples for water content analysis were collected monthly throughout the growing season, at 0–15 cm, 15–30 cm and 30–60 cm depth intervals. The samples were bagged onsite and sent to a laboratory for analysis of soil moisture parameters, specifically total water (percent weight basis), field capacity, wilting point and texture. Plant available water was calculated as the difference between total water and wilting point of the soil samples.

Crop yield

Crop yield measurements were conducted on annual crops in the fall by harvesting by hand square meter samples from each plot. The cut samples were collected and transported in paper bags and allowed to air dry in a storage facility in Calgary. To obtain grain yield measurements, the samples were oven dried, threshed and weighed at a crop research facility in Calgary. Total seed weight and weight per 1,000 seeds were recorded.

Statistical analysis

Statistical analyses were performed using STATISTIX Version 8.0. Data obtained from the study was analyzed with respect to the year it was collected (2002, 2003 and 2004). The study consisted of a split-split plot design where the sites were treated as homogenous blocks. Analysis of variance (ANOVA) was employed

Table 2. Year 2003 mean plant available soil water (%)

Sampling location	Depth in soil profile 0–15 cm	15–30 cm	30–60 cm	Location means
Centreline	8.07 ± 0.5 a	6.67 ± 0.5 a	4.06 ± 0.3 a	6.26 ± 0.3 a
2 m off centre	8.14 ± 0.4 a	6.63 ± 0.4 a	4.09 ± 0.4 a	6.99 ± 0.3 a
13 m off centre	7.85 ± 0.4 a	6.58 ± 0.5 a	3.71 ± 0.4 a	6.05 ± 0.3 a

Note: Means within columns with the same letter are not significantly different ($p > 0.05$).

Table 3. Year 2004 mean plant available soil water (%)

Sampling location	Depth in soil profile 0–15 cm	15–30 cm	30–60 cm	Location means
Centreline	10.3 ± 0.5 a	9.79 ± 0.5 a	6.43 ± 0.5 a	8.83 ± 0.3 a
2 m off centre	10.4 ± 0.5 a	9.49 ± 0.6 a	6.24 ± 0.4 a	8.74 ± 0.3 a
13 m off centre	10.5 ± 0.4 a	9.19 ± 0.5 a	6.38 ± 0.4 a	8.69 ± 0.3 a

Note: Means within columns with the same letter are not significantly different ($p > 0.05$).

to detect significant differences ($p < 0.05$) between the main effects (Month in Growing Season, Depth in Soil Profile and Distance from Pipeline) and their subsequent interactions. Post-hoc comparisons of treatment means were conducted using the Tukey test in order to correct for experimentwise error rate at an alpha level of 0.05.

RESULTS

Soil heating

On average at Site 2, where the pipeline temperature was highest, measured soil temperature at the 15 to 30 cm depth range over the pipe centreline was 3–5 C higher than 2 m adjacent to the centerline and 8–10 C higher than 13 m adjacent to the centreline. At Site 1, with the lowest pipeline temperature, measured soil temperature at the 15 to 30 cm depth range over the pipe centreline was 1–2 C higher than 2 m adjacent to the centreline and 2–4 C higher than 13 m adjacent to the centreline. Sites 3, 4 and 5 consistently fell within this range of soil heating at the 15–30 cm depth with declining temperature differences between centreline and adjacent sites as the distance of the sites from the compressor station increased.

Plant available soil water

Sites 2, 3, and 5 provided sufficient data for inclusion in soil water combined sites analyses for year 2002. Total measured soil water and wilting point were used to calculate the variable plant available soil water (%). Analyses revealed no significant three-way interaction between the three factors distance from pipeline, depth in soil profile and month of growing season ($p > 0.05$). No significant two-way interactions were observed for distance from pipeline and depth in soil profile ($p > 0.05$) and distance from pipeline and month of growing season ($p > 0.05$). Mean plant available soil water was significantly higher ($p < 0.05$) on the centerline (3.21 ± 0.42) than 13 m off the centerline (2.27 ± 0.41) (Table 1).

Sites 1, 2, 3 and 5 provided sufficient data for inclusion in soil water combined sites analyses for year 2003. Total measured soil water and wilting point were used to calculate the variable plant available soil water (%). Analyses revealed no significant three-way interaction between the three factors distance from pipeline, depth in soil profile and month of growing season ($p > 0.05$). No significant two-way interactions were observed for distance from pipeline and depth in soil profile ($p > 0.05$) and distance from pipeline and month of growing season ($p > 0.05$). Mean available plant soil water showed no significant difference across the three levels of distances ($p > 0.05$) (Table 2).

Sites 1, 2, 3, and 5 provided sufficient data for inclusion in soil water combined sites analyses for year 2004. Total measured soil water and wilting point were used to calculate the variable plant available soil water (%). Analyses revealed no significant three-way interaction between the three factors distance from pipeline, depth in soil profile and month of growing season ($p > 0.05$). No significant two-way interactions were observed for distance from pipeline and depth in soil profile ($p > 0.05$) and distance from pipeline and month of growing season ($p > 0.05$). Mean plant available soil water showed no significant difference across the three distances ($p > 0.05$) (Table 3).

Crop yield

Due to poor growing conditions and crop failures in 2002, crop yield data was obtained from Sites 2 and 5 only. In 2003 crop yield data was obtained from Sites 1, 2 and 3.

Table 4. Year 2002 crop yield (Total seed weight (g/sq m)

Sample location	Site 2	Site 5
Centreline	170.1 ± 1.5 a	58.6 ± 37.9 a
2 m off centre	167.2 ± 8.9 a	43.4 ± 14.3 a
13 m off centre	197.4 ± 14.3 a	15.6 ± 7.8 a

Note: Means within columns with the same letter are not significantly different ($p > 0.05$).

Table 5. Year 2003 crop yield (Total seed weight (g/sq m)

Sample location	Site 1	Site 2	Site 3
Centreline	278.4 ± 35.1 a	480.9 ± 11.2 a	475.5 ± 41.6 a
2 m off centre	240.0 ± 6.8 a	472.1 ± 31.3 a	430.8 ± 63.6 a
13 m off centre	331.3 ± 23.9 a	443.6 ± 62.2 a	401.8 ± 28.2 a

Note: Means within columns with the same letter are not significantly different ($p > 0.05$).

The field at Site 2 was seeded to barley in 2002. No significant differences were observed for grain yield among the three sample locations (Table 4). The field at Site 5 was seeded with wheat in 2002. Again, no significant differences were observed for grain yield among the three sample locations (Table 4).

In 2003, the field at Site 1 was seeded to canola, the field at Site 2 was seeded to barley and the field at Site 3 was seeded to wheat. No significant differences were observed at any of the 2003 sites for grain yield among the three sample locations (Table 5).

DISCUSSION

Soil temperature

From the results of the soil temperature monitoring it is evident from this study that heat from the pipeline causes heating of the soil within the effective rooting zone for annual crops (upper 60 cm) as far as 190 km (120 mi) downstream of compressor stations. As expected, the largest soil heating effect was measured at sites closest downstream of compressors with a corresponding reduction in heating of the rooting zone as distance from the compressor increases.

Available soil water

Through the course of this study, plant available soil water was measured during three growing seasons with differing precipitation regimes: 2002 was a year of very low rainfall; 2003 was a near normal rainfall year; and 2004 was a year with above average rainfall during the growing season. The results from this study indicate that the increased soil temperature above the pipeline does not affect the availability of soil water for plant growth. Soil temperature in most cases did not seem to have a significant effect among sample locations (pipe centerline, 2 m off centerline, and 13 m off centerline) on available soil water.

Based on published literature, it was expected that heat from the pipeline would warm the surrounding soil, resulting in a drying effect, and therefore less water in the vicinity of the pipeline. However, in at least one case the opposite was observed; in 2002 available water tended to be higher along the centerline or 2 m off centre, compared to the control site 13 m off centre.

Crop yield

Better moisture during the growing season of 2003 compared to 2002, allowed for better growing conditions and consequently more complete yield data collection for the soil heating study than the previous year. However, crop yield was not significantly different among sample location on the right-of-way at any of the sites where annual crop yield data was measured.

CONCLUSIONS

Although the study results presented here are interim since, to date, not all data has been collected an analyzed, one important preliminary conclusion from the study may be put forward. The heating of rooting zone soil by the pipeline did not have a significant effect on plant available soil water. Further studies in different regions and years would be useful to test the validity of this finding.

REFERENCES

Alberta Agriculture, Food and Rural Development. 2002. Soil Group Map of Alberta. Website: http://www1.agric.gov.ab.ca/soils/soils.nsf.

Alberta Environmental Protection. 1994. Natural Regions, Subregions and Natural History Themes of Alberta. A classification for protected areas management. Report 2. 72 pp.

Alberta Environmental Protection. 1998. Natural Regions and Subregions of Alberta. 1:1:000,000 map.

Burgess, M.M. and S.L. Smith. 2001. Shallow ground temperatures. Bulletin of the Geological Survey of Canada. 547: 89–103.

Holmes, N.D., G.R. McNaughton, W.E. Phillips, J.G. Stothart, and J. Willman. 1976. Alberta Farm Guide. Edmonton, AB. 336 pp.

Kaspar, T.C. and W.L. Bland. 1992. Soil temperature and root growth. Soil Science 154(4): 290–299.

Ketcheson, J.W. 1970. Effects of heating and insulating soil on corn growth. Can. J. Soil Sci. 50: 379–384.

McMaster, G.S., W.W. Wilhelm, D.B. Palic, J.R. Porter, and P.D. Jamieson. 2003. Spring wheat leaf appearance and temperature: extending the paradigm? Annals of Botany 91: 697–705.

McMichael, B.L. and J.J. Burke. 1998. Soil temperature and root growth. HortScience 33(6): 947–951.

Naeth, M.A. 1985. Ecosystem reconstruction and stabilization following pipeline construction through Solonetzic native rangeland in southern Alberta. M.Sc. Thesis, University of Alberta, Edmonton. 196 pp.

Naeth, M.A., D.S. Chanasyk, W.B. McGill, and A.W. Bailey. 1993. Soil temperature regime in mixed prairie rangeland after pipeline construction and operation. Can. Agricultural Engineering. 35(2): 89–95.

Nixon Geotech Ltd. 1998. Geothermal analysis for Alliance Pipeline near Fort Saskatchewan, Alberta. Prepared for Alliance Pipeline Ltd.

Rykbost, K.A., L. Boersma, H.J. Mack, and W.E. Schmisseur. 1975a. Yield Response to Soil Warming: Agronomic Crops. Agronomy Journal 67(6): 733–738.

Rykbost, K.A. L. Boersma, H.J. Mack, and W.E. Schmisseur. 1975b. Yield Response to Soil Warming: Vegetable Crops. Agronomy Journal 67(6): 738–743.

Spencer, F.S. 1975. Plant growth over an underground power transmission prototype. Ontario Hydro Research Quarterly 27: 17–23.

Stewart, A.J. and A.F. MacKenzie. 1979. Effect of pipeline construction on soils and crops. IV. Department of Renewable Resources, Macdonald College, Montreal, Quebec. 43 pp.

Stone, P.J., I.B. Sorensen, and P.D. Jamieson. 1999. Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool-temperature climate. Field Crops Research. 63(2): 169–178.

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Part X
Pesticides

Ultra Low Volume Applications for Rights-of-Way

Joe Lentz

Asplundh Tree Expert Co. teamed up with DuPont recently to develop the ultra low volume (ULV) Thinvert herbicide application system for chemically side trimming rights-of-way. This system has shown potential for up to 40 percent improvement in productivity while maintaining effective vegetation control. The Thinvert application system and Krenite S, a bud inhibitor, have been tested for the past four spray seasons to selectively treat woody plants that threaten to interfere with the conductors. A two person crew, equipped with a lift truck, bucket sprayer unit can ULV side trim the walls in conjunction with the pole saw operation. This system makes it possible to treat 2,500 lineal feet of right-of-way daily at a rate of five to seven gallons per vertical acre. Both operational and demonstration plot work will be presented. Data from plots in Minnesota to Florida have been analyzed to determine if ULV side trimming is a viable tool for the utility vegetation manager. Additional applications such as ULV cut stubble, backpack, and broadcast foliar will be discussed.

Keywords: Right-of-way vegetation management, ultra-low volume applications of herbicides, ULF side trimming, controlling unwanted vegetation

UTILITY VEGETATION MANAGEMENT

Vegetation management has come a long way since the days of high volume 300 to 400 gallon per acre broadcast applications of the 50's, 60's and 70's. The first transition to low volume took place in the 60's with mist blower applications and in the mid 1980's with low volume basal treatments. The 1990's introduced low volume backpack treatments with water based solutions. This evolution to low volume has required the vegetation manager to shorten the treatment cycle and strengthen their budget commitment. This commitment to low volume application has proven to provide reliable power and stockholder value. Low volume applications are a viable tool when target stem densities are low (1,500 stems per acre) and height is 8 ft. or less.

The 1990's also brought the inception of ultra low volume (ULV) applications, utilizing the Thinvert Application System®. A patented system introduced by Tex Waldrum and Roy Johnson of Waldrum Specialties Inc., the Thinvert Application System is a combination of specially designed ultra low volume nozzles and a thin invert carrier. Thinvert RTU® is a combination of phyto-bland paraffinic oil, surfactants, emulsifiers and water, blended with water to form a thin invert emulsion. Thinvert RTU® is then mixed with herbicides at the specified rate and applied using specially designed ULV nozzles.

The treatments include: ULV broadcast foliar, ULV side trimming, ULV cut stubble, and ULV backpack. These application rates vary from 1 to 7.5 gallons per acre, typically 70% less volume than water-based applications.

BENEFITS OF ULV APPLICATION WHEN UTILIZED PROPERLY

Ultra low volume applications provide the vegetation manager a low profile method of providing long-term control of undesirable trees that interfere with reliable power to the end user.

The follow are a list of objectives that are met via ULV applications.
- High percentage of control;
- Productivity;

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- Minimal under story damage;
- No off target drift;
- Rainfastness;
- Visibility, fewer misses and less over application; and
- Reduced equipment needs.

ULV Broadcast Foliar

Rights-of-way that have been reclaimed by mechanical methods, such as a brush hog, Hydro-ax, or Kershaw, will result in as much as 10 times the stem count, depending on the soil, species, and management approach in the past. Follow up herbicide applications and rates can vary depending on the history of a given right-of-way (ROW).

The ULV Broadcast Foliar application consists of a treatment to the mowed ROW, utilizing the Thinvert application system at a rate of 5 gallons per acre. This can be accomplished with a gasoline-powered backpack sprayer or an ATV.

The ATV setup consists of a rear-mounted 25 gallon tank with a Honda engine, Hypro roller pump, two Widecast™ nozzles and Thinvert resistant hoses. Two Widecast™ nozzles mounted on an ATV will cover a 25–30 foot wide swath on brush up to 6 feet high at a total volume of 5 gallons per acre. The re-sprouts should be hardened off to insure a high percentage of control.

Typical rates are, as follows:

– Accord Conc. (Glyphosate)	1 gal. per acre;
– Escort XP (Metsulfuron Methyl)	1 oz. per acre;
– Arsenal (Imazapyr)	14 oz. per acre; and
– Thinvert RTU	3.75 gal. per acre.

If conifers are present:

– Krenite S (Fosamine)	1 gal. per acre;
– Escort XP (Metsulfuron Methyl)	1 oz. per acre;
– Arsenal (Imazapyr)	14 oz. per acre; and
– Thinvert RTU	3.75 gal. per acre.

The application is more suitable on 15, 30 or 60 ft. wide ROW because the ultra low volume makes it difficult to see the coverage. Therefore, one or two swaths reduce the risk of misses. At a rate of 5 gallons per acre, very little, if any, of the mixture comes in contact with the ground. The risk of off target damage from root pick up has not been observed in operational applications. The percentage of control by vegetation managers has been documented at 90 to 95%. Control is measured by counting the stems per acre before treatment and counting the stems 1 and 2 years after application.

ULV cut stubble

Cut stubble is defined as an application of soil active, selective herbicides after immediately mowing when the ground is NOT frozen or saturated. Historically, the application has been made with water at 50 gallons per acre. This application is ideal for reclaiming a ROW for future ULV backpack applications, eliminating the need for mowing.

ULV cut stubble applications allow the treatment to be made at a rate of 5 gallons per acre, reducing the need for costly equipment while at the same time decreasing worker exposure. The ATV set-up used for broadcast foliar applications can also be used for ULV cut stubble.

Transmission corridors are ideal for cut stubble. It's important to keep a 10 ft. buffer on the ROW edge to reduce the risk of root pick up from desirable trees. Distribution corridors are too narrow and are not good candidates for cut stubble.

Typical Rates for cut stubble are, as follows:

– Tordon K (Picloram)	½ gal. per acre;
– Arsenal (Imazapyr)	1 pt. per acre; and
– Thinvert RTU	4.34 gal. per acre.

Note: Calibration is critical to the success of the program.

The percentage of control typically is between 85% and 100%. This is dependent on soil, species, application, and timing. If present before mowing, Russian Olive appears to escape this application. Otherwise, a variety of forbs, herbs, and grasses that appear after a cut stubble application help to create competition for undesirable woody vegetation.

ULV backpack foliar

After ULV applications using an ATV and Widecast nozzles, the number of brush stems on the right-of-way will be reduced. Now a ULV backpack spray the following year (if needed), with repeat ULV low profile sprays every three to five years will keep the lines accessible and help reduce outages, while controlling brush maintenance budgets.

ULV Thinvert backpack sprays usually apply only 2 to 5 gallons spray mix per acre for follow-up treatment, so heavy equipment isn't required to get to the site and to supply product. Ultra low volume sprays also minimize injury to desirable ground cover vegetation.

Typical rates are, as follows:

– Accord Conc. (Glyphosate)	7%;
– Escort XP (Metsulfuron Methyl)	1 gm. per gal.;
– Arsenal (Imazapyr)	1%; and
– Thinvert RTU	92%.

– Krenite S (Fosamine)	7%;
– Escort XP (Metsulfuron Methyl)	1 gm. per gal.;
– Arsenal (Imazapyr)	1%; and
– Thinvert RTU	92%.

ULV side trim

With thousands of miles of off-road rights-of-way to maintain, utility vegetation managers need to consider all the tools available to them. It helps to have a long-term, environmentally sound perspective and a plan to find the most effective method, or combination of methods, for the dollars spent.

There are at least three ways that a right-of-way can be side trimmed, as follows:

- manually with climbing crews;
- mechanically with rubber-tired or tracked lifts and boom mounted cutters; and
- herbicide applications.

Choosing the right tool for the job is important. Just as you wouldn't use a sledgehammer to drive a tack into drywall, likewise you may not always need specialized equipment to side trim.

A new variation on side trimming—using the ultra low volume Thinvert herbicide application system—shows potential for up to 40% improved productivity with effective control. Depending on the location and condition of the right-of-way, ULV side trimming can be a great tool in the vegetation management toolbox.

For many years, side trim applications with water have been used on both roadside and utility rights-of-way. Krenite S was applied at a rate of 1½ to 2 gallons per 100 gallons of water to vegetation laterals extending into the ROW. Krenite S has a mode of action that inhibits the bud from leafing out the year after application. Therefore, the lateral cambial tissue is still green the year after application. The tree is not stressed by a mechanical cut and does not respond by sending out numerous shoots. Departments of Transportation all over the United States continue to utilize this application to improve safety with better visibility of signs, bends in the roadway, and intersections.

Historically, only utilities in the southern states applied Krenite S in water as a hydraulic application to laterals impeding the power line corridor. However, the disadvantages were significant: expensive equipment, low productivity, sporadic control, problems with drift, and most of all, the high profile or visibility of the application to the public.

Asplundh has been developing ULV side trimming as a unique addition to its trim lift/ pole saw side trimming operation. Over the past 4 years, several ULV side trim plots have been created in various regions of the country. These areas include: Texas, Arkansas, Louisiana, Florida, Georgia, Virginia, West Virginia, Ohio, Kentucky, Missouri, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Pennsylvania, New Jersey, and Delaware. Operational crews in Virginia, Arkansas, Texas, Pennsylvania, Delaware, and New Jersey have increased production, reliability, and reduced cost.

OBJECTIVE

The objective is to determine the efficacy of the ULV Sidetrim application on a variety of species in different geographic locations. A series of plots have been established utilizing the ULV Thinvert Application System® for side trimming laterals that will grow into the power lines. The treatments were made during the 2003 growing season.

The brush control agent applied was Krenite S from E.I. Dupont. Krenite S is a bud inhibitor that prevents areas treated from leafing out the following year. As a result, they cannot make food and eventually die. It has been noted that the stem tissue of treated laterals will often still be green one year after application. In many cases, results are not noticeable for one growing season with the exception of conifers. Conifers tend to show effects immediately. Half-life, depending soil types, can be as low as 1 day.

Krenite has a history of being weak on Hickory, Poplar, Box Elder, Elm, Sassafras, and Black Gum. Therefore, low rates of Arsenal were added to the Krenite S 10% rate. Arsenal rates were 1 oz. per 2½ gal. (.3%), and 2 oz. per 2½ gal. (.6%).

Three applications were evaluated, as follows:

- Krenite S 10%;
- Krenite S 10% + Arsenal (.3%); and
- Krenite S 10% + Arsenal (.6%).

Application

The Thinvert Side-trimm'r™ application system is attached to the bucket of a standard 55-foot aerial lift. The system requires that the herbicide, Krenite S, be blended with Thinvert RTU®. This thin invert emulsion encapsulates the herbicide to reduce drift, provides uniform droplets and improves the wetability, penetration and absorption into the plants' stomata.

Using a Widecast™ #1554 nozzle, which creates a 15-foot swath of uniform droplets, it is possible to daily treat 2,500 linear feet at a rate of 5 to 7 gallons per vertical acre. Since Krenite S is a bud inhibitor, the applicators were careful to only treat lateral limbs growing toward the conductors and not to treat the tops of trees (the terminal bud) where injury cannot be tolerated. Low-growing species were not treated unless targeted. It was also important to consider the amount of backside growth on the target trees in order to leave enough foliage to keep the tree alive.

Rating the results

The method to rate the results was based on the growth or lack of it the year after treatment.

Each plot and species was rated, as follows:

- 0% control — No control observed;
- 25% control — Application error, missed targets or minimal control;
- 50% control — Treated laterals leafed out with minimal stem elongation;
- 75% control — Treated laterals leafed out, no elongation of stem; and
- 90–100% control — No leaf out of treated laterals.

Table 1. Identifies the states, species, and percentage of control using Krenite S at 10% with Thinvert RTU

Species	VA	NJ	MN	MD	IL	WV	WI	PA		Average
Ash	5	5				5		5	20	**5.0**
Tulip Poplar	2					2		2	6	**2.0**
Sweet Gum	4	4							8	**4.0**
Live Oak	5								5	**5.0**
White Oak	5			5	4	4	3	4	25	**4.2**
Red Oak	5	5	4		5	5	3	5	32	**4.6**
Holly	3								3	**3.0**
Red Maple	5	5		5	4	4		4	27	**4.5**
Sassafras	2	2						2	6	**2.0**
Cottonwood	3								3	**3.0**
Sycamore	5								5	**5.0**
White Pine	5	5	3				4	5	22	**4.4**
Loblolly Pine	5								5	**5.0**
Virginia Pine	5			5					10	**5.0**
	59	26	13	22	22	25	10	34		
Overall Control	**4.2**	**3.7**	**2.6**	**3.7**	**3.7**	**4.2**	**3.3**	**3.1**		

Table 2. Identifies the states, species, and percentage of control using Krenite S at 10% and Arsenal at .3% with Thinvert RTU

Species	VA	NJ	MN	MD	IL	WV	WI	PA		Average
Tulip Poplar	4					4		4	12	4
Sweet Gum	5	5							10	5
Live Oak	5								5	5
White Oak	5			5	5	5	5	4	29	4.8
Red Oak	5	5	5		5	5	3	5	33	4.7
Holly	3								3	3
Red Maple	5	5		5	4	4		4	27	4.5
Sassafras	5	5						4	14	4.7
Cottonwood	4								4	4
Sycamore	5								5	5
White Pine	5	5	3				4	5	22	4.4
Loblolly Pine	5								5	5
Virginia Pine	5			5					10	5
	66	35	23	29	27	28	12	44		
Overall Control	**4.7**	**5.0**	**4.6**	**4.8**	**4.5**	**4.7**	**4.0**	**4.0**		

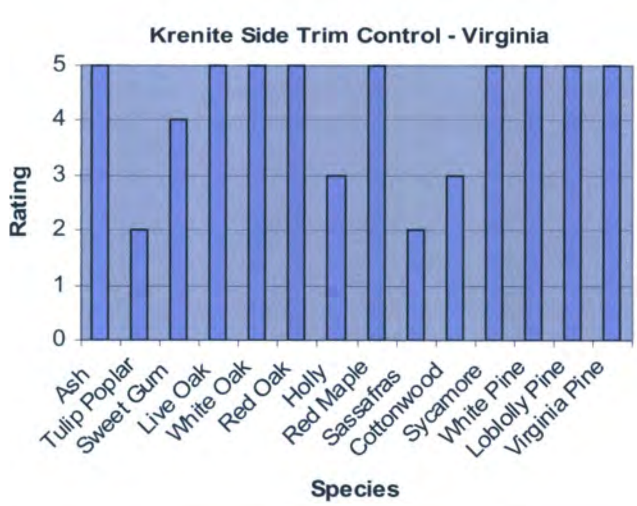

Fig. 1. Identifies the states, species, and percentage of control using Krenite S at 10% with Thinvert RTU.

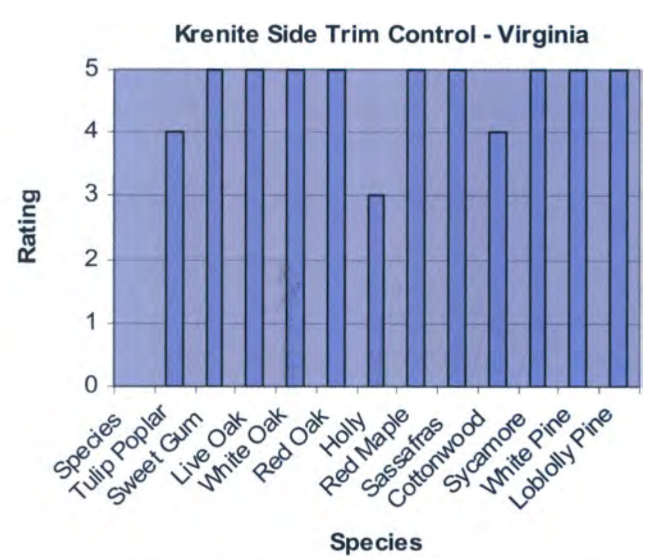

Fig. 2. Identifies the states, species, and percentage of control using Krenite S at 10% and Arsenal at .3% with Thinvert RTU.

EVALUATIONS AND RECOMMENDATIONS

ULV Sidetrim applications were first conceived in 2000 by DuPont, Waldrum Specialties, Arborchem Products Co. with cooperation from Conectiv and AEP. It has been a work in process to fine tune the rates, products, and application equipment.

Krenites mode of action is to inhibit the buds from leafing out the year after application. The year of application show no obvious signs of treatment. Treated laterals, one year after application do not leaf out. There is no effect on limbs that were not treated. The ULV application is designed to increase the productivity of a trim lift operator by providing additional tools, the ULV side trim application in conjunction with the pole saw operation. Equipment, rates, and applications are discussed below are a compilation of all involved.

Equipment

Initially a 15 ft. Widecast Nozzle was used to increase productivity. It had an undesirable effect by increasing over spray and under story damage. The Thinvert brush gun, nozzles SS081531 and SS15105, allowed the applicator more flexibility.

The SS081531 provides a 3–4 ft. swath with an 8 ft. reach. The SS15105 provides a 1 ft. swath with a 15 ft. reach. Together there is more applicator precision treating laterals that threaten contact with energized conductors.

Rates and product

Krenite has an excellent track record over the past 30 years in roadside vegetation management programs. Determining a rate for ULV Side Trim was a trial and error process. It was determined that Krenite S 10% is a good rate. It met the program objectives needed to consider it a viable tool. Krenite is weak on a variety of species. Therefore, it is necessary to add ½–1 oz. Arsenal per 2½ gal. of Krenite–Thinvert Mix when Sassafras, Box Elder, Black Gum, Hickory, Poplar, and Elm are present.

Application

Initially, the application was made to encroaching limbs from ground to sky. Trees that border the forest on one side and the right-of-way on the other have very few laterals opposite the ROW due to being shaded. When the terminal bud and the ROW side were treated, the result was dead trees. Therefore, it was determined that the upper 15 ft. of the crown stay intact. Treating the wire zone produced favorable results and met objectives. Laterals that threaten reliability are cut with the pole saw.

Do not treat trees that are not tall enough to support a reduced canopy.

Observations

It is necessary to evaluate the application in July–August of the following growing season for accurate results. Krenite often bottles the growth of the laterals. If the lateral still has leaves, it often does not grow. In some cases, White Pine appeared to show no signs of control; however, if no candle is produced the following year, control is evident. Arsenal @ ½–1 oz. per 2½ gal. of Krenite 10% and Thinvert is recommended when species require it. Reclaiming side wall mechanically and treating resprouts in 2 to 3 years reduces impact.

Trees 30 ft. tall or less should not be treated unless damage can be tolerated. Geographic location has an impact on the rates and procedures.

CONCLUSION

An ULV side trim treatment is a viable tool when used in conjunction with mechanical pruning methods. Coverage is essential for achieving good control. Training is also a critical component to insure that the objective is met. Applicators comment that the ULV Side trim application method is easier, less strenuous and more productive that the pole saw operation. Utility foresters who are operational agree that ULV Side Trim is a viable tool for line clearance.

When all the criteria are met, the increased productivity and efficacy indicate that this technique is favorable to add to vegetation management tool box.

BIOGRAPHICAL SKETCH

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Part XI
Aquatic Life

Lake Erie Link Project: Assessment of Potential Construction Effects of Electric Cable Crossing(s) of Lake Erie

J. Fitchko, M. Ernst, B. McCormick, and L. Gresock

An independent electric transmission system has been proposed beneath Lake Erie to interconnect networks in Ontario and Pennsylvania (or Ohio). Existing international interconnections at either side of Lake Erie tend to experience limitations on inter-regional electricity exchange during peak demand periods. The proposed Lake Erie Link (LEL) Project, consisting of up to three high voltage direct current cable crossings with a potential to transmit 1,000 MW of electricity, would enhance system reliability and improve competitive markets on both sides of the international border. Primary issues and concerns addressed through route selection and environmental assessment (EA) efforts included offshore natural gas development on the Canadian side, areas of anthropogenic use (e.g., anchorage areas, dredge spoil disposal sites), submerged historic/archaeological resources, lake bottom morphometry and substrate characteristics affecting constructability, and biologically sensitive areas. Effects of surface and shallow bedrock blasting were evaluated based on previous construction blasting experience in the Lake Erie near shore. The assessment of contaminant release during cable installation was based on route-specific sediment quality data. Turbidity plume generation and siltation due to directional drilling and jetting was assessed by conservative modeling. Risk-based models were used to determine cable burial depths providing acceptable levels of risk with respect to ice scour and anchor dragging. Overall, based on the EA and application of recommended mitigative measures, it was concluded that the LEL Project would have minor, short-term and localized adverse environmental effects. The proposed LEL Project is currently on hold for commercial reasons.

Keywords: Electric, routing, assessment, Lake Erie, North America

INTRODUCTION

The Lake Erie Link (LEL) is an independent electric transmission system proposed by subsidiaries of TransÉnergie U.S. Ltd. and Hydro One Delivery Services that will interconnect the electric transmission networks in Ontario with those in western Pennsylvania or possibly in Ohio. The LEL will consist of up to three underground and underwater cables (traversing Lake Erie), which would employ modular high voltage direct current (HVDC) technology, each with bi-directional transfer capability of approximately 325 megawatts (MW). A converter station will be located at the ends of each cable system for interconnection with existing aboveground alternating current (AC) transmission networks. The LEL cable system technology is used because it has many advantages over AC technology for long distance power transmission, including the ability to control power flow direction, system voltage support, the absence of cooling liquid in the cables and smaller cable bundles to transmit an equivalent amount of power.

The purpose of the LEL is to develop a fully controllable, bi-directional electrical transmission interconnection between Ontario and Pennsylvania (or Ohio) to improve both the reliability of the North American power grid and the competitiveness of the respective electricity markets. Existing international interconnections at either side of Lake Erie tend to experience limitations on inter-regional electricity exchange during

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peak demand periods. By providing a direct connection between Ontario and Pennsylvania (or Ohio), the LEL will enhance system reliability on both sides of the border by establishing an additional path for power supplies to flow when and where they are needed. The LEL will provide energy producers and consumers in each region with a direct path to each other, leading to greater availability and trade in electricity.

The proposed LEL will involve the construction of converter stations on or near existing overhead AC transmission system rights-of-way, and underground HVDC cables trenched from the converter stations to the Lake Erie shore lands. Construction from the landfall into the near shore area of Lake Erie will be accomplished by horizontal directional drill (HDD) from the shore into the lake and/or conventional and shallow water trenching activities, including bedrock cutting, ripping and/or blasting. Further offshore, the cable crossing will involve installation by a cable lay barge and lowering of the cable below the lake bed by water jetting or other suitable technique.

In the United States, a number of environmental and engineering permits will be required at the federal, state and local levels, including a Presidential Permit from the U.S. Department of Energy for projects involving international transmission of electricity, prior to construction and operation. An independent Environmental Report (ER) has been prepared and filed with the U.S. Department of Energy for the proposed LEL from the Canada-U.S. international border to converter stations in East Springfield, Pennsylvania (TRC et al., 2002). The LEL has received approval for its interconnection with the existing utility grid from the Federal Energy Regulatory Commission (FERC, 2002).

In Canada, international transmission lines are under the jurisdiction of the National Energy Board (NEB). As a pre-condition to the exercise of regulatory authority of the NEB and other federal decision-makers, project approval is required under the *Canadian Environmental Assessment Act* (CEA Act). The LEL is also subject to other federal, provincial and local authorizations/permits. A scoping document/terms of reference (HONS, 2002) has been submitted to the NEB in compliance with the CEA Act. A comprehensive environmental assessment report was nearing completion for the proposed LEL from the U.S.-Canada international border to transformer stations in Nanticoke, Ontario, when the project was put on hold for commercial reasons.

LANDFALL AND ROUTE SELECTION

The general landfall near Nanticoke, Ontario, was selected because of the presence of existing and robust transmission facilities associated with the Ontario grid. There are very few locations where high voltage transmission lines approach the Ontario shoreline of Lake Erie. The selected location also minimizes the distance necessary for the interconnection between Ontario and the U.S. The preferred site-specific landfall selection was based on avoiding or maximizing distance from a number of physical constraints/sensitive receptors.

Potential landfalls on the U.S. side in Pennsylvania and Ohio were similarly selected based on their proximity to existing transmission lines and land availability (ESS, 2000a; 2002b; TRC, 2001). The preferred landfall sites were selected based on the following criteria: real estate, constructability and cost, terrestrial ecology, soils/wetlands, water protection/aquatic ecology, cultural resources, contamination potential, land use, nuisance/noise-sensitive receptors, traffic disruption and aesthetics (TRC, 2001).

Based on these pre-determined landfall locations, an evaluation of alternative lake crossing routes was undertaken based on criteria presented in Table 1. The location of the preferred route and landfalls is indicated in Fig. 1.

ENVIRONMENTAL BASELINE

A substantial amount of environmental information on Lake Erie has been published in the technical literature. To augment this information and provide site- and route-specific information, terrestrial environment, wetland, sediment quality, benthic macroinvertebrate and fisheries resources surveys (Eakins and Fitchko, 2002; Fitchko, 2002a; 2002b; 2002c; Fitchko and Dickison, 2002; Kaiser and Fitchko, 2002; TRC et al., 2002) were undertaken. A geophysical/geotechnical survey of the preferred Lake Erie crossing route was also undertaken involving the collection of high resolution side scan sonar, high frequency sub-bottom profiling, bathymetry and marine magnetometer data (CSR, 2002). An assessment of the submerged cultural and heritage resources was based on these data (Herdendorf, 2002). Phase 1 archaeological assessments were also completed for the land portions of the project (Poulton, 2002; TRC, 2002).

ASSESSMENT OF CONSTRUCTION EFFECTS

Construction activities with a potential to have the most significant negative effect on the environment include blasting, bedrock cutting/ripping, conventional dredging and HDD for cable trenching in the Lake Erie near shore, cable burial by water jetting in the offshore and the institution of a construction exclusion zone to water uses.

Blasting

Blasting, if necessary, can have negative (acute/chronic) effects on fish and benthic organisms. Based on monitoring studies during the construction of a 1,200-m long dock at Nanticoke over a four-month period, up to 40,000 emerald shiner and up to 50 freshwater

Table 1. Lake Erie crossing routing criteria

Criteria	Preferred route selection
Offshore natural gas development on the Canadian side	Avoid the natural gas pipeline collection system or minimize the number of pipeline crossings
Ice scour of lake bottom documented in water depths up to 25 m with highest frequency at about 10 m (C-CORE, 1999)	Minimize route length in water depths of 20 m or less, and avoid bathymetric high spots such as ridges and escarpments
Commercial vessel anchor dragging	Minimize route length in commercial traffic area and avoid designated anchorage areas
Turbidity generation and siltation	Avoid or minimize the length of traversal of areas with fine-grained sediment
Sediment quality	Avoid areas of toxic sediments and fine-grained recent sediment deposition and maximize traversal of non-depositional areas with glaciolacustrine till or coarse-grained sediment
Biological sensitivity	Avoid designated sensitive habitat areas and consider characteristics of nearshore areas to minimize effect to sensitive habitat
Areas of anthropogenic use	Avoid dredge disposal locations and commercial sand and gravel dredging areas
Submerged cultural resources	Avoid all known submerged cultural resources, e.g., trench around shipwrecks along cable route
Constructability	Avoid areas of excessive slope and known or anticipated areas of large boulders
Route length	Minimize route length

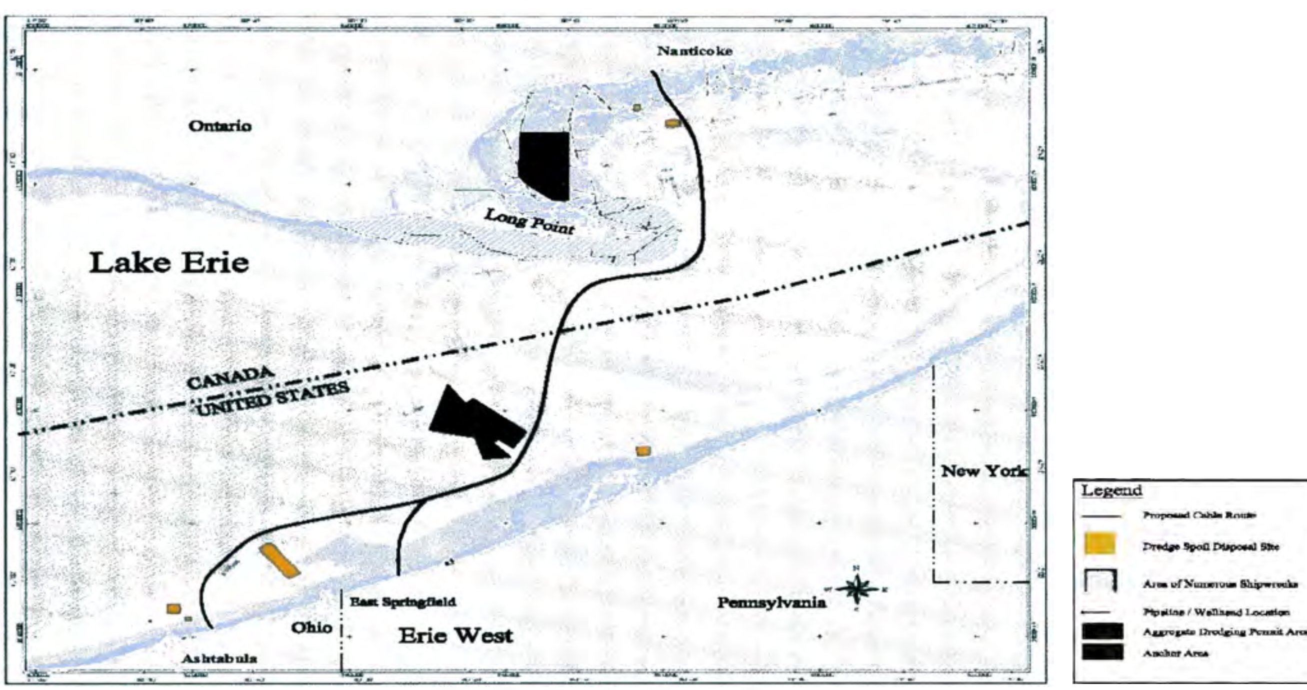

Fig. 1. Location of preferred route and landfalls.

drum were killed per blast (Chamberlain, 1976; 1979; Teleki and Chamberlain, 1978). Only a few individual economically important species, such as perch and bass, were killed. Results of ultrasonic tracking suggested that these fish remained outside the fatal blast area. As fish losses were not considered serious by the provincial government agency, protective air bubble curtains or other mitigative measures were not used. Emerald shiner and freshwater drum populations returned to normal by the following year. Similar effects on fish populations can be expected as a result of blasting during LEL construction. Bedrock cutting/ripping would have negligible effect on fish populations. Blasting, if necessary, and bedrock cutting/ripping would have some effect on the benthic macroinvertebrate communities; however, recovery of these communities can be expected within one year (see Direct Effects of Trenching).

Drilling mud loss

During HDD, drilling mud will be lost at the exit hole in the near shore lake bed. The drilling mud is predicted to form a thin dense plume along the lake bed and will likely flow towards deeper water (van Arkel, 2002a; 2002b). The large density difference between the drilling mud and lake water is expected to keep the drilling mud from mixing with the overlying water unless high ambient currents are present (e.g., during a storm event). Based on conservative modeling under calm conditions, maximum plume sizes with total suspended solids (TSS) concentrations greater than 1,000 mg/L and 10,000 mg/L would be 550 m^2 and <18 m^2, respectively, for less than one month (van Arkel, 2002a; 2002b). Under storm conditions, the maximum plume sizes with TSS concentrations greater than 1,000 mg/L and 10,000 mg/L would be 330 m^2 and <18 m^2, respectively. Under both scenarios, maximum deposit thickness of drilling mud on the lake bottom after settling is estimated to be 1 mm. The 1,000 mg/L TSS concentration value represents the approximate threshold at which few, if any, sublethal effects are elicited in most fish species, e.g., behavioral (avoidance), histopathological and plasma chemistry effects, whereas the 10,000 mg/L TSS concentration value represents the approximate threshold mortality level for some fish species exposed for 24 hours or longer (Fitchko, 1999). Due to the low toxicity of drilling mud and the small areas over which elevated TSS concentrations are predicted, negligible effects on fish can be expected. Due to their mobility, fish can avoid areas of elevated TSS concentrations. Some mortality of sedentary benthic filtering organisms can be expected due to the demersal location of the plume and at this exposure duration, with rapid recovery by recolonization and recruitment after construction cessation.

Turbidity generation due to jetting

To obviate potential ice scour damage, the cables will require burial into the lake bottom sediments by conventional dredging in the near shore and water jetting in deeper waters. For the jetting operation, a self-propelled jetting tool will straddle the cable after it is laid on the lake bottom. High-pressure water will then be injected into the sediments through a series of forward-facing nozzles on the remotely-operated tool causing the cable to sink through the column of liquefied sediment. Much of the liquid sediment will sink back into the trench; however, some will become resuspended and disperse through the water column before settling some distance from the trench. Conventional dredging and jetting will result in turbidity generation and siltation, physical disruption of bottom habitat and potential chemical release from the sediments.

Based on conservative modeling of the jetting operations, maximum plume sizes with TSS concentrations greater than 1,000 mg/L and 10,000 mg/L are 0.2 km^2 and 0.02 km^2, respectively (van Arkel, 2002a; 2002b). Due to the transitory nature of jetting, organisms will be exposed to TSS concentrations greater than 10,000 mg/L for 6 hours or less. No mortality of adult fish is expected based on available toxicity data and avoidance reaction. However, some mortality of larval fish and filtering organisms (e.g., zooplankton) is possible. Based on very conservative assumptions, up to about 27,600 larval fish could be exposed during the spring and summer to a turbidity plume with TSS concentrations greater than 10,000 mg/L at any point along the cable route in the near shore, i.e., to water depths of about 20 m, with the potential total effect equivalent to the annual production of about 830 adult rainbow smelt and/or yellow perch. In comparison, based on Ontario commercial fishery catch data, about 191,200,000 female rainbow smelt and 5,408,000 female yellow perch were landed in 2000 in Canadian Lake Erie waters. During late summer and fall construction, up to about 5,040 young-of-the-year (YOY) and yearling fish (primarily rainbow smelt) would be exposed to a turbidity plume with TSS concentrations greater than 10,000 mg/L at any point along the cable route. Due to their mobility, these YOY and yearling fish can avoid areas of elevated TSS concentrations. During jetting, maximum deposit thickness is estimated to be 42.6 mm within 20 m, with deposits less than 4 mm within 363 m of either side of the trench. Little, if any, mortality of benthic organisms is expected due to vertical migration from the hyporheic zone (i.e., after burial).

Direct effects of trenching

The physical disruption of bottom habitat due to trench excavation by mechanical jetting and/or conventional dredging equipment may have a localized adverse effect on aquatic communities on the lake bed and within the substrate. Based on very conservative assumptions, it was estimated that the potential direct effects of trench excavation for all cable crossings would be equivalent to the annual egg and/or larval production equal to or less than about 292 and 156 adult rainbow smelt and yellow perch, respectively. As indicated above, 191,200,000 female rainbow smelt and 5,408,000 female yellow perch were landed by the Ontario commercial fishery in 2000. Direct destruction of benthic fauna communities will result in changes in species composition, abundance and diversity. However, recovery is anticipated within six days to one year (Rosenberg and Snow, 1977; Griffiths and Walton, 1978; Griffith and Andrews, 1981; Diaz, 1994; McCabe et al., 1998).

Chemical release from sediments

Chemical analyses have confirmed that the sediment along the proposed cable route can be reasonably characterized as uncontaminated by toxic chemicals based on regulatory guidelines and background levels. Any chemical releases are expected to be small, their effects will be localized and temporary, and rapid dispersion by mixing and sorption processes to ambient levels is expected. Considering the short duration of exposure, the probability of any quantifiable bioconcentration of contaminants by fish is low. Similarly, no net effects on benthic macroinvertebrates are predicted, since these organisms are in contact over their lifespan with the chemical constituents in the sediments (interstitial waters).

Table 2. Summary of other project-related effects

Effect	Significance assessment
Obstruction of migration or passage of wildlife	Fish and birds can by-pass areas of disturbance
Negative effect of visible turbidity	Based on conservative modeling, the maximum visible plume size in the nearshore will be about 4 km^2 and will persist for about 30 h after cessation of trenching operations (van Arkel, 2002); in water depths less than 20 m and under normal hydrodynamic conditions (i.e., no storm events), turbidity plumes generated at the directional drill exit hole and by jetting at bottom are not expected to reach the lake surface, and therefore will likely not be visible; in water greater than 20 m (the average thermocline depth), turbidity plumes generated by jetting will not be visible
Negative effects of inadvertent returns on lands due to HDD	Removal for subsequent re-use and/or approved disposal
Negative effects on recreational opportunities	Transitory restrictions to boat access; however, most of the project corridor will always be open for boat transit/usage
Negative effects on commercial navigation	Construction vessels will be fitted to conform with regulations; most of the project corridor will always be open for boat transit
Negative effects on heritage resources	Shipwreck(s) to be avoided; any land facilities heritage resources sites to be mitigated
Nuisance effects	Construction vessels may have minor positive or negative aesthetic effects
Restrictions on natural gas exploitation	A restriction zone to be established along the cable for protection
Restriction on possible future aggregate extraction	Very small areas (glacial till) with very low aggregate potential along the cable route will become unavailable for potential future exploitation

Effects on water uses

Turbidity plumes generated by HDD and jetting operations may affect the nearest municipal water intakes located 1.4 km and 6.2 km from the cable route on the Canadian and U.S. sides, respectively. However, water treatment plants can remove excess quantities of suspended solids by screening, coagulation, sedimentation and filtration. It is expected that the efficiency of these treatment processes will be sufficient to provide acceptable potable water supplies for distribution during the short duration (14–41 hours) of elevated TSS concentrations.

A temporary exclusion zone as wide as 500 to 1,000 m on either side of the cable route may be established during cable-laying and trenching activities, and may extend over the entire seven-month period of in-lake construction. Commercial fishing in Ontario waters of Lake Erie is mainly undertaken by diesel-powered tugs, with gillnetting for yellow perch, walleye and other fish species undertaken in shallower waters, i.e., generally less than 25 m, and trawling for pelagic rainbow smelt beyond the 20-m bathymetric contour. The cable route occurs at depths as great as 62 m. Based on an exclusion zone of 1 km on either side of the cable route and the anticipated schedule for sequential in-lake construction of these cables, Fitchko (2002d) estimated that the combined (gillnetting and trawling) commercial catch value that could be affected by in-lake construction activities would be $21,337 (Canadian). This catch value represents only about 0.07% of the average annual catch value for the Ontario waters of Lake Erie between 1996 and 2001. Commercial fishing, primarily by trap nets, is undertaken on a significantly smaller scale on the Pennsylvania and Ohio waters of Lake Erie. During cable construction, fishers can continue to utilize the extensive areas outside of the exclusion zone. It was concluded that the institution of an exclusion zone should not measurably affect the total commercial catch (and associated value) from Ontario, Pennsylvania and Ohio waters of Lake Erie during LEL construction.

Other construction effects

Other construction effects, such as noise, equipment exhaust emissions and interference with other water uses (e.g., recreational/commercial boating), will be short-term, localized and of low magnitude. These effects can be further minimized by proper equipment maintenance, good housekeeping practices, mitigative measures implementation, and appropriate notification of project location and schedule. Table 2 provides a summary of other potential negative effects and their significance.

ASSESSMENT OF OPERATIONAL EFFECTS

Cable damage

During operation, ice scour, commercial fish bottom trawling and anchor dragging/dropping have the potential to damage the cables. As indicated above, the cables will be buried into the lake bottom to obviate ice scour damage. Scouring has been identified in much of Lake Erie, particularly in shallower waters and toward the eastern end of the lake due to the predominant wind direction. When the ice cover becomes fractured, the predominantly westerly winds cause the pile-up of ice and the formation of pressure ridges. Ice scour occurs when the moving ice piles up and forces ice

Table 3. Recommended trench depths by cable zone from the Canadian to Pennsylvania landfalls

Zone	Kilometre post interval	Average water depth (m)	Sediment type	Average soil strength	Scour rate (no./km/y) used for risk analysis	Approximate burial depth (m)
A	0.0–0.6	2.5	Bedrock	–	–	Into bedrock
B	0.6–1.9	7	Silt/clay (>4 m thick)	25 kPa	1×10^{-2}	2
C	1.9–2.3	8	Silt/clay (≤0.5–3 m) over bedrock	25 kPa/-	1×10^{-2}	2
D	2.3–2.9	7	Silt/clay (≤0.5–3 m) over bedrock	25 kPa/-	–	3 (Into bedrock)
E	2.9–3.5	9	Silt/clay (≤0.5–3 m) over bedrock	25 kPa/-	3.5×10^{-3}	2
F	3.5–5.9	9	Bedrock	–	–	Into bedrock
G	5.9–10.2	16	Silt/clay (≤0.5–4 m)	25 kPa	3.5×10^{-2}	4
H	10.2–11	21	Silt/sand (>4 m thick)	37 deg	1.1×10^{-2}	2
I	11–13.5	26	Silt/clay (>4 m thick)	25 kPa	3.5×10^{-3}	2
J	13.5–61	>30	Silt/clay (deep water)	25 kPa	1.1×10^{-5}	1
K	61–75.6	26	Silt/clay (>4 m thick)	25 kPa	5.2×10^{-3}	2
L	75.6–77.8	24	Silt/sand (>4 m thick)	37 deg	7.0×10^{-3}	2
M	77.8–91	23	Silt/clay (>4 m thick)	25 kPa	1.1×10^{-2}	2
N	91–106.9	16	Silt/clay (>4 m thick)	25 kPa	1.02×10^{-1}	3
O	106.9–107.2	11	Silt/clay (≤ 0.5–4 m) over bedrock	25 kPa/-	4.32×10^{-1}	3
P	107.2–108.8	6	Bedrock	–	–	Into bedrock

underneath the ice ridges resulting in the scraping of the lake bottom. Most scours are less than 1 m deep. However, in the soft substrate of Long Point Bay near Nanticoke, trenches several kilometres long, varying in width from a few meters to over 100 m, and up to 1.7 m deep have been recorded (Grass, 1981a; 1981b; 1985; Grass and Johnston, 1982).

The potential for ice scour caused by pressure ridges along the proposed cable crossing was analyzed by C-CORE (2002). A risk-based model was used to delineate 16 zones along the cable route from the Canadian to the U.S. landfall based on average water depth, average soil strength, ice scour regime and design criteria (cable strain). This model was used to predict the likelihood of ice scour effects to the cable at various depths of burial so that a depth could be specified with an acceptable level of risk. Ice scour in the area of bedrock or very dense sediment would result in insignificant penetration, i.e., only surface scraping. However, softer, less resistant sediments are easily scoured by ice. Moreover, ice scour has not been documented at water depths greater than 25 m (C-CORE, 1999).

Table 3 summarizes the average water depth, average soil strength and ice scour frequency for the 16 zones delineated by C-CORE (2002) for the cable route between the Canadian and Pennsylvania landfalls, and provides the recommended trench depths for each zone based on 0.01 annual probability of exceeding 0.1% strain. Installation at these depths would provide for adequate cable protection and minimize the potential for future cable damage. A maximum trench depth of 1 m was recommended in waters with depths greater than 30 m. However, the actual burial depth along zone J will be about 2 m for additional cable protection and due to jet technology efficacy in the removal of the soft, fine-grained sediments present within this zone. The recommended depths of burial would also satisfy lakebed incursions associated with fishing activities, e.g., trawl board drag over the cable (C-CORE, 2002). Risk of damage from trawl gear is negligible provided a minimum cable burial depth of 1 m is implemented.

The effects of dragged and dropped objects such as anchors and the probability that these events will damage the cable have also been assessed by C-CORE (2002). It was impossible to designate a practical depth for dragged or dropped anchors. The risk of a dragged anchor affecting the cable is 6×10^{-3} (1 in 180 years), whereas for a dropped anchor, the risk is 6×10^{-5} (1 in 17,000 years), respectively. To mitigate this risk, the cable would be clearly marked on all navigational charts for the lake and "Notice to Mariners" would be issued to all commercial vessels traversing the lake. The cable system would include a fibre optic cable for communications between the two interconnecting converter stations and for the redundant protective relaying system, which will continuously monitor the voltage and current in the cable. This system will disconnect the cable from the interconnected transmission systems in approximately 0.1 second or less in the unlikely event of damage.

Other operational effects

During operation, the submarine cables under Lake Erie, as well as the upland cables, which converge at the converter station site, will not carry AC power and so will not produce either AC electric or magnetic fields. The only effect of the cables on the ambient electrical environment will be on the local geomagnetic field as a weak magnetic field source (Exponent, 2001). While a number of species are reported to be capable of detecting changes in the Earth's magnetic field, the narrow linear feature of the field around the cables makes it unlikely that long distance navigation, migration, or major behavioral patterns of those species would be affected. The effect of the cable system on the DC magnetic field at the surface of Lake Erie would be too weak to materially affect compass readings. Very small changes in the intensity and direction of the ambient DC magnetic field over the buried cables has no known significance with respect to human health.

Thermal resistivity studies of the sediments along the cable route indicate that there is likely to be no more than a 0.1°C temperature increase at the sediment/water interface. This small increase will not have a measurable effect on sediment characteristics, benthic or water column biota, water quality or water uses.

RESIDUAL AND CUMULATIVE EFFECTS

No significant adverse residual (post-mitigation/restoration) effects are anticipated based on implementation of recommended environmental protection and mitigation procedures.

Based on assessment of interactions with other site-specific developments in the vicinity of proposed construction and activities directed at renewable resources utilization, and taking into account the construction of up to three cables in a sequential fashion, it was concluded that the proposed LEL project will have negligible negative cumulative effects.

Project construction could be considered to have a positive residual and cumulative effect on the local and regional economics associated with job creation, direct material and supply purchases, as well as retail and commercial spending. In addition, the completed cable project will result in tax revenues paid annually to the municipal governments, again resulting in a positive cumulative effect. Finally, the LEL project will have additional electric transfer capacity between the U.S. and Canada improving both the reliability of the North American power grid and the competitiveness of the respective electricity markets.

CONCLUSIONS

Based on an assessment of available baseline information and potential effects, as well as the application of recommended mitigative measures, it was concluded that the project, primarily due to its transitory nature, will have minor, localized and short-term environmental effects that are not likely to result in significant adverse effects. Environmental protection will also be ensured by compliance with regulatory standards and guidelines. Finally, adherence to a tight construction schedule with minimum lag between activities will minimize project effects on the environment.

REFERENCES

Canadian Seabed Research Ltd. (CSR). 2002. Lake Erie Link Project Marine Geophysical & Geotechnical Survey Results. Report to Hydro One Delivery Services Inc. and TransÉnergie U.S. Ltd. 28 p.

Centre for Cold Ocean Resources Engineering (C-CORE). 1999. Lake Erie Ice Scour/Pipeline Design. Contract Report to TransCanada PipeLines Limited. Memorial University of Newfoundland, St. John's, Newfoundland. C-CORE Publication 98-C34. 98 p.

Centre for Cold Ocean Resources Engineering (C-CORE). 2002. Lake Erie Link Project (Nanticoke, Ontario to Springfield, Pennsylvania): Ice Scour and Cable Burial. Contract Report to TRC Environmental Corporation and TransÉnergie U.S. Ltd. Memorial University of Newfoundland, St. John's, Newfoundland. C-CORE Contract Report R-01-08-635.

Chamberlain, A.J. 1976. The Acute and Subacute Effects of Underwater Rock Blasting, Dredging and Other Construction Activity on the Fishes in the Nanticoke Region of Long Point Bay, Lake Erie. Report No. 1, Construction Phase 1 March-November 1975. Ontario Ministry of Natural Resources. 117 p.

Chamberlain, A.J. 1979. Short-term Effects of Dock Construction Activity on Fishes in the Nanticoke Region of Long Point Bay, Lake Erie. Report 2, Construction Phase 2, March-November 1976. Ontario Ministry of Natural Resources. 50 p.

Diaz, R.J. 1994. Response of tidal freshwater macrobenthos to sediment disturbance. Hydrobiologia 278: 201–212.

Eakins, R. and J. Fitchko. 2003. Nearshore Fisheries Resources Assessment, Proposed Lake Erie Link Project. Beak International Incorporated Draft Report to Hydro One Delivery Systems Inc. 9 p.

Environmental Science Services, Inc. (ESS). 2000a. Evaluation of Potential Pennsylvania Sites and Upland Routes for Proposed Canada to United States Interconnection Project. Report to TransÉnergie U.S. Ltd. 5 p.

Environmental Science Services, Inc. (ESS). 2000b. Evaluation of Potential Ohio Sites and Upland Routes for Proposed Canada to United States Interconnection Project. Report to TransÉnergie U.S. Ltd. 6 p.

Exponent. 2001. Electric and Magnetic Field Assessment: Cross Sound Cable Project. Report to Cross-Sound Cable Company, LLC. 35 p.

Federal Energy Regulatory Commission (FERC). 2002. TransÉnergie U.S. Ltd. and Hydro One Delivery Services, Inc. 98 FERC Para. 61, 147.

Fitchko, J. 1999. Critical Review of Suspended Sediment Criteria for Freshwater Ecosystems. Beak International Incorporated Draft Report to TransCanada PipeLines Limited.

Fitchko, J. 2002a. Sediment Quality Assessment, Proposed Lake Erie Link Project (Canadian Waters). Beak International Incorporated Draft Report to Hydro One Delivery Systems Inc. 16 p.

Fitchko, J. 2002b. Benthic Macroinvertebrate Community Survey, Proposed Lake Erie Link Project (Canadian Waters). Beak International Incorporated Draft Report to Hydro One Delivery Systems Inc. 13 p.

Fitchko, J. 2002c. Sediment Quality Assessment, Proposed Lake Erie Link Project (U.S. Waters). Beak International Incorporated Draft Report to TRC Environmental Corporation. 21 p.

Fitchko, J. 2002d. Assessment of Potential Impacts of the Proposed Lake Erie Link Project on Commercial Fisheries. Beak International Incorporated Draft Report to Hydro One Delivery Systems Inc.

Fitchko, J. and J. Dickison. 2002. Benthic Macroinvertebrate Community Survey, Proposed Lake Erie Link Project (U.S. Waters). Beak International Incorporated Draft Report to TRC Environmental Corporation. 16 p.

Grass, J.D. 1981a. Ontario Hydro – GPU Interconnection, Lake Erie Submarine Cable Crossing, Ice Scour Study. Ontario Hydro Report No. 80463: 9 p.

Grass, J.D. 1981b. Ontario Hydro – GPU Interconnection, Lake Erie Submarine Cable Crossing, Ice Scour Study. Ontario Hydro Report No. 81317 (Supplementary to Report No. 80463): 6 p.

Grass, J.D. 1985. Lake Erie cable crossing – ice scour study, pp. 1–10. *In:* R. Pilkington [Ed.]. Workshop on Ice Scouring, Assoc. Comm. Geotech. Res., National Research Council, Ottawa, Ontario.

Grass, J.D. and O.A. Johnston. 1982. Ontario Hydro – General Public Utilities Interconnection, Lake Erie Cable Crossing, Ice Scour Evaluation. Ontario Hydro Report No. 82032: 9 p.

Griffith, J.S. and D.A. Andrews. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. N. Amer. J. Fish. Mgt. 1: 21–28.

Griffiths, R.W., D.W. Schloesser, J.H. Leach, and W.P. Kovalak. 1991. Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes region. Can. J. Fish. Aquat. Sci. 48: 1381–1388.

Griffiths, W.H, and B.D. Walton. 1978. The Effects of Sedimentation on the Aquatic Biota. Renewable Resources Consulting Services Ltd. Report to Alberta Oil Sands Environmental Research Program. AOSERP Report 35.

Herdendorf, C.E. 2002. Lake Erie Link Project Underwater Archaeology Report for Canadian and United States Waters of Lake Erie. Phase 1 Cultural Resources Investigation of the Proposed Lake Erie Link Project from Nanticoke, Ontario to Springfield, Pennsylvania and Ashtabula, Ohio. EcoSphere Associates Report to TRC Environmental Corporation. 46 p.

Hydro One Network Services Inc. (HONS). 2002. Lake Erie Link 150 kV Submarine Cable, Environmental Assessment Scoping Development. Prepared for Hydro One Delivery Services Inc. 44 p.

Kaiser, J. and J. Fitchko. 2002. Inventory and Assessment of the Natural Features and Terrestrial Communities Associated with the Land-based Facilities, Proposed Lake Erie Link Project. Beak International Incorporated Draft Report to Hydro One Networks Inc. 14 p.

McCabe, G.T., Jr., S.A. Hinton, and R.L. Emmett. 1998. Benthic invertebrates and sediment characteristics in a shallow navigation channel of the lower Columbia River, before and after dredging. Northwest Sci. 72: 116–126.

Poulton, D.R. & Associates Inc. (Poulton). 2002. The Stage 1 Archaeological Assessment of the Proposed Lake Erie Link Project (Canadian Facilities), Nanticoke, Geographic Township of Walpole, Haldimand County, Ontario. Draft Report to Beak International Incorporated and the Ontario Ministry of Tourism, Culture and Recreation. 13 p.

Rosenberg, D.M. and N.B. Snow. 1977. A design for environmental impact studies with special reference to sedimentation in aquatic systems of the MacKenzie and Porcupine River drainages, pp. 65–78. *In*: Proc. Circumpolar Conf. Northern Ecology. 15–18 September 1975, Ottawa.

Teleki, G.C. and A.J. Chamberlain. 1978. Acute effects of underwater construction blasting on fishes in Long Point Bay, Lake Erie. J. Fish. Res. Board Can. 35: 1191–1198.

TRC Environmental Corporation (TRC). 2001. Lake Erie Link Project Facilities Routing and Siting Analysis. Report to TransÉnergie U.S. Ltd.

TRC Environmental Corporation (TRC). 2002. A Cultural Resource Survey for the TransÉnergie Buried Cable and Converter Station in Erie County, Pennsylvania. Report to Lake Erie Link LLC c/o TransÉnergie U.S. Ltd.

TRC Environmental Corporation, Beak International Incorporated, Canadian Seabed Research Ltd., C-CORE, EcoSphere Associates, Ecology & Environment, Inc. and Urban Engineers of Erie (TRC *et al.*). 2002. Lake Erie Link Project Environmental Report. Report to Lake Erie Link LLC c/o TransÉnergie U.S. Ltd.

van Arkel, G. 2002a. Suspended Sediment Plume Prediction, Proposed Lake Erie Link Project (Canadian Waters). Beak International Incorporated Draft Report to Hydro One Delivery Systems Inc. 12 p.

van Arkel, G. 2002b. Suspended Sediment Plume Prediction, Proposed Lake Erie Link Project (U.S. Waters). Beak International Incorporated Draft Report to TRC Environmental Corporation. 13 p.

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Impacts of Power Line Rights-of-Way on Forested Stream Habitat in Western Washington

Nancy Claire Gleason

Pacific Salmon *Oncorhynchus* spp. have inhabited streams of the Pacific Northwest for millennia. In the past century, however, many populations have suffered severe declines and even extinction, largely due to settlement of the West Coast. Hydroelectric dams, an artifact of industrialization, necessitate swaths through forests to extend powerlines from generating facilities to consumers. Rights-of-way are cleared of trees, and roads are built for equipment access. Many rights-of-way that cross streams in forested areas cause disturbances to riparian zones. Salmonids are sensitive to disturbances that lead to altered temperatures, lack of dissolved oxygen, and increased sedimentation. This project's objective was to quantify effects of rights-of-way on forested streams by comparing right-of-way and paired upstream habitat. Measurements included benthic macroinvertebrates, canopy cover, fish presence, water quality, and percentage of fine particles (< 0.85 mm) in streambed gravel to determine suitability as spawning habitat. The only parameter that was significantly different was canopy cover with a mean of 29% in rights-of-way and 75% upstream. The parameters were expected to show degradation in the right-of-way due to opened canopy and gravel roads. The results, however, do not confirm the hypotheses. Overall, the elements show a decrease from ideal salmonid habitat conditions. It is likely that the streams intersected by rights-of-way have recovered from the initial disturbances that occurred 30 to 50 years ago, and have restabilized to a natural regime. It is also possible that any degradation caused by rights-of-way is masked by wider scale disturbances such as timber harvest and off-road vehicle activities.

Keywords: Habitat, macroinvertebrates, Pacific Northwest, Pacific salmon, right-of-way, stream

INTRODUCTION

Overview

Pacific Salmon *Oncorhynchus* spp. have inhabited streams of the Pacific Northwest for thousands of years. In the past century; however, many populations of these wild, anadromous fish have suffered severe declines and even extinction. This is largely due to the impact from settlement and industrialization of the West Coast. This has meant over-harvest of salmon stocks, damming of rivers for irrigation and hydropower, harvest of almost all old-growth forest, development of vast areas of lowlands, and urbanization especially in the Puget Sound region.

Concerns for salmonid habitat in rights-of-way stem from the knowledge base of forestry and fish interactions in the Pacific Northwest. One of the key points this body of literature stresses is the importance of maintaining intact riparian zones. Salmonids are stressed by the specific types of disturbances in the riparian zone that lead to altered temperatures, lack of dissolved oxygen, and increased turbidity (Bjornn and Reiser, 1991). Health of the riparian forest is important because it is the "last line of defense" for preserving the health of the instream habitat (Dominguez and Cederholm, 1996). Powerline rights-of-way begin with land clearance even more thorough than a timber harvest clearcut, a primitive road is established, and then forest succession is arrested with chemicals thus preventing reclosure of canopy that shaded the stream. It is possible that powerline rights-of-way cause fragmentation of riparian corridors and negatively impact stream habitat due to the vegetation management regime and lack of road maintenance.

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

This information raises questions as to whether riparian buffers are adequate, whether invasive plants increase, whether canopy removal changes invertebrate community structure and increases stream temperatures, and whether herbicides affect fish or food sources for invertebrates. Also of interest are the probability of large woody debris recruitment, the likelihood of sedimentation due to decreased root structure, and whether land clearing affects microclimate. Although there are over 100 studies on wildlife issues in rights-of-way, only a small percentage dealt with impacts to fish, and none were salmonids in the western United States. Answering the aforementioned questions regarding riparian zones will rely on a combination of information from right-of-way studies and from forestry and salmon habitat investigations.

Impacts of rights-of-way to biological integrity of riparian zones

The US Fish and Wildlife Service's guidelines for right-of-way management near streams encourage keeping stream bank vegetation intact and enhancing erosion control (Galvin et al., 1979). Riparian Management Zones have also been codified in Washington's Forest Practices Rules (WAC, 1987). Watersheds within King County are subject to King County Code, Chapter 21A.24, which governs "Critical Areas" of fish and wildlife habitat. Wetland buffers range in width from 15 m to 90 m (KCC, 2001). However, utility corridors are permitted alterations to the aquatic habitat buffer standards. A corridor can be located in the outer third of a buffer, and reduction is permitted where a roadway transects a buffer. Maintenance of utility service connections and installation of new lines are exempt from provisions of Chapter 21A, but require a Critical Area Report, and specific criteria apply whenever a stream is crossed. Red alder *Alnus rubra*, big leaf maple *Acer macrophyllum*, and cottonwood *Populus trichocarpha* dominate the riparian zones, but the prolific sprouting capabilities and rapid growth rate make these trees the most likely to be removed as "danger trees" (Hett and Baumert, 1988). Beschta et al. (1987) emphasize the importance of remaining cautious when harvesting timber near streams based on studies of impacts of riparian vegetation removal on stream temperatures. Furthermore, a study of pre- and post-harvest microclimate variables resulted in the recommendation that riparian buffer zones be no narrower than 45 m (Brosofske et al., 1997).

Luken et al. (1991) found that vegetation removal causes an abrupt edge to forest habitat and changes the dynamics of the local ecology. In a study of six managed rights-of-way and their neighboring forested habitat, the rights-of-way all had greater cover of non-natives indicating that rights-of-way are more susceptible to non-native colonization due to disturbance from line construction and maintenance (Cameron et al., 1997). Despite environmental mitigation efforts during right-of-way establishment of a pipeline through boreal forest, construction activities facilitated the introduction of 34 alien taxa and 13 native invasive taxa to the right-of-way (Cody et al., 2000). Analogous findings came from an inventory of vegetation on a right-of-way in Whatcom County, Washington, an area with similar climate, floral, and faunal species to King County. Boss (1974) found that alien plant species achieved more coverage in the middle of a right-of-way, especially along the access road, and natives remained at the edges of the right-of-way in close proximity to the surrounding forested land. In fact, 48% of inventoried species were non-native, and 71% were regarded as weeds. Land clearing for the right-of-way was the initial disturbance, but the frequent road usage by both recreational users and maintenance workers was blamed for compaction and continued disturbance that resulted in a preponderance of successful shade-intolerant non-natives. Several of the invasive species inventories in the Whatcom county right-of-way currently are on the King County Noxious weed list, including reed canary grass *Phalaris arundinaceae*, scotch broom *Cytisus scoparius*, and two thistle species *Cirsium* spp. The vegetation management regime of chemical application and continued frequent disturbance by recreational and maintenance vehicles will likely maintain the herb-shrub community in the right-of-way as well as continue the trend of invasion by weeds (Boss, 1974).

Naiman et al. (2000) emphasize the importance that biological elements of river ecology have for microclimates riparian zones. This is important for effective conservation strategies because there are strong biological influences on physical elements of river ecology. It is important for land managers to recognize the physical and biological feedback systems. Despite efforts to minimize impacts of powerlines, the necessity of tree-free corridors in the western hemlock zone can produce a disturbance that may affect microclimate. Brosofske et al. (1997) studied microclimates of five streams pre- and post-harvest. Pre-harvest values showed a stream-to-upland gradient that generally reached forest interior values at 31–62 m from the stream. Post-harvest climatological data showed interruption or elimination of this gradient. Furthermore, stream climate was affected by width of buffer and surrounding area microclimate. Stream-to-upland gradients existed for air temperature, surface air temperature, soil temperature, and relative humidity. Stream temperature was highly correlated with soil temperature before harvest, but not as strongly after harvest, likely due to the difference in hydrology between clearcuts and intact forests (Brosofske et al., 1997). Other important findings are that wider buffers increased relative humidity and decreased solar radiation for the stream habitat.

For rights-of-way that are of minimum width and cross a stream with a large riparian buffer, there may be sufficient vegetation to maintain normal stream temperatures. However, where high voltage distribution crosses a forested stream, localized warming of exposed area can cause detrimental changes in stream temperatures. Stream flow measurements from gauged watersheds reveal that lack of vegetative cover can also affect snow melt rate (Herrington and Heisler, 1973). Microclimatological data of wind speed and radiation in the western Cascades showed that snow melt in clear cuts produces triple the water delivery of coniferous canopy and occurs at an altered rate from natural conditions (Berris and Harr, 1987).

Combining right-of-way management and salmon ecology

The developing strategies of Integrated Vegetation Management focus on minimizing manual labor and quantities of herbicides, and how to combine mechanical and chemical methods for sustainable shrub communities and tree suppression (Niering and Goodwin, 1974; Finch and Shupe, 1997; Ramsay and Parker, 2001). After minimizing vegetation-related power outages and maintenance costs, a secondary concern in right-of-way management is the maintenance of wildlife habitat.

Research projects addressing stream habitat, water quality, and benthic invertebrate communities following right-of-way construction have concluded with varying results. Several studies focusing on buried pipeline installation found that initial construction and long-term presence of a right-of-way can change structure and composition of riparian habitat, contribute suspended sediments and bed load, and alter downstream water quality (Cordone and Kelley, 1961; Blais and Simpson Jr., 1997). Other studies showed only temporary impacts such as a single season of decreased benthic invertebrate populations (Baddaloo, 1978). Zallen's (1984) study of mountain whitefish in British Columbia found no significant impact of a pipeline right-of-way on incubating eggs and juveniles. A study of stream habitat quality in upstate New York following pipeline installation showed decreasing numbers of fish in one of the six study streams, but there were no consistent patterns of impacts to other streams (Blais and Simpson Jr., 1997). In a study of paired right-of-way and upstream sections, disturbed habitat had no significant differences in water temperatures or quantity of erosion (Garant et al., 1997).

Peterson (1993) studied trout habitat in powerline rights-of-way in New York and found a higher number of fish within the rights-of-way than in the adjacent undisturbed areas. He attributed this to the greater number and depth of pools. Greater density of stream bank vegetation stabilized banks, thus causing water velocity to scour substrate instead of eroding banks, which in turn created the deeper pools. Impacts of right-of-way disturbances on fish populations are not as well documented as the disturbance effects of turbidity and sedimentation on benthic invertebrates (Blais and Simpson Jr., 1997). A review of investigations on impacts of increased turbidity and sedimentation to aquatic biota concluded that all trophic levels can suffer decreased productivity from increased sedimentation (Cordone and Kelley, 1961).

In the realm of salmonid ecology research, impacts of timber harvest and logging road construction have received much attention due to their widespread impact on the Pacific Northwest landscape and importance to the regional economy. Peterson et al. (1992) compiled and summarized the research on impacts of logging roads and timber harvest in a report on cumulative effects. The percent of basin area covered by logging roads correlates to levels of fine sediment in downstream gravel (Cederholm et al., 1981). This information is relevant to the study of rights-of-way because of the similarity of a right-of-way to a roaded, clearcut patch of an otherwise forested landscape. Other important work has been done in the realm of water quality analysis by analyzing the benthic macroinvertebrate community assemblages and creating a scoring system known as the Benthic Index of Biotic Integrity (Karr and Dudley, 1981). This is a highly valuable method of assessing the health of streams.

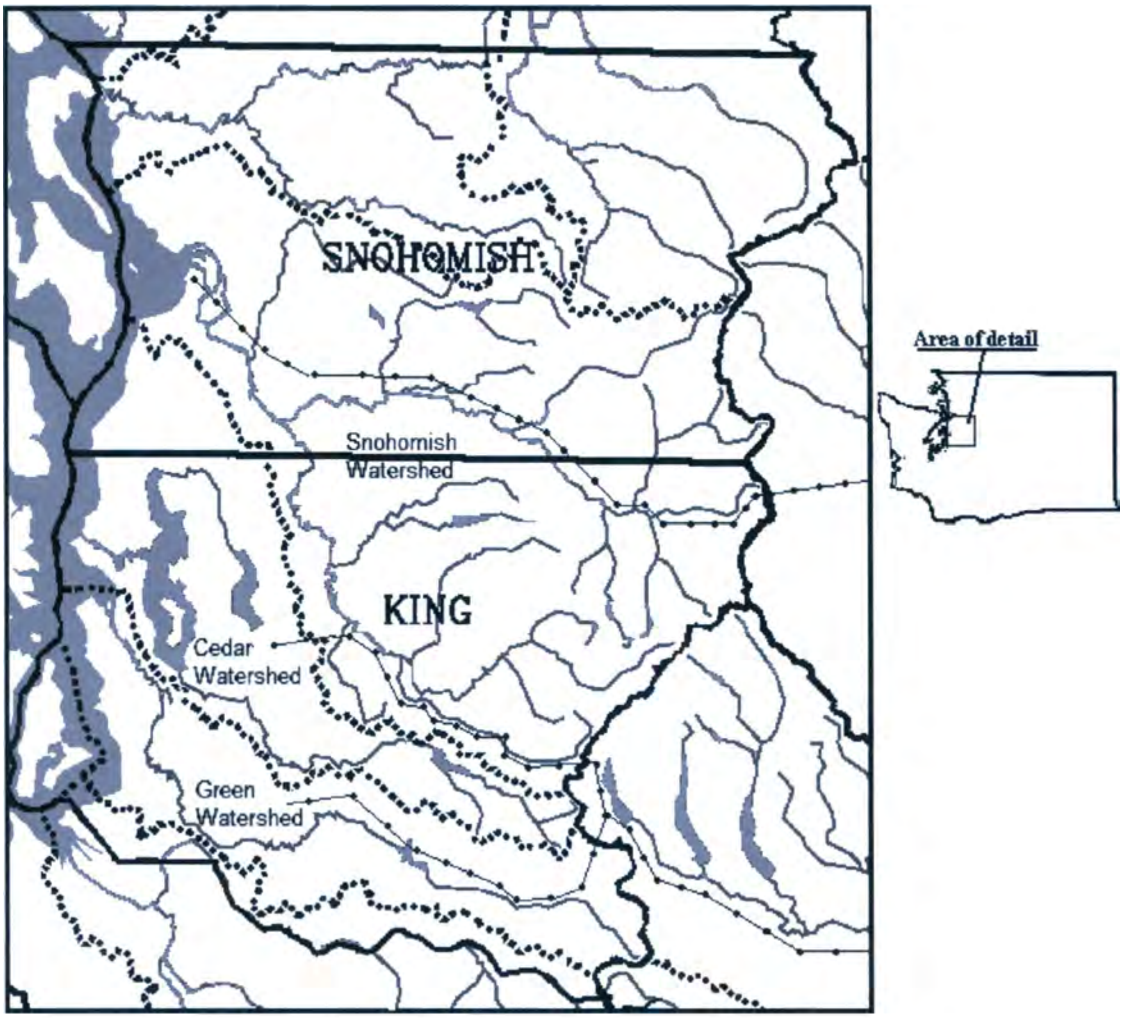
Research objectives

The goal for this project was to determine how the establishment and maintenance of powerline rights-of-way effects stream habitat intersected in the forests of Western Washington. To achieve this objective, certain habitat characteristics were focused on in order to measure the extent of the impact of rights-of-way on riparian zones and salmonid habitat. The investigation took place in the Snohomish River and Green River watersheds where high voltage powerlines follow major river valleys from the Cascade crest to regional substations. These powerline rights-of-way cross many small tributaries as the lines distribute electricity to the growing population of the Puget Sound region.

The goals were to check road crossings for passability by salmonids, and to compare the health of habitat within rights-of-way and the paired upstream reaches using the following parameters:

- Use the Benthic Index of Biotic Integrity (B-IBI) to compare benthic macroinvertebrate communities;
- Survey for fish to determine presence or absence;
- Measure percentage of fine particles (< 0.85 mm) in streambed gravel to compare quality of spawning habitat; and
- Sample water quality for temperature, dissolved oxygen, pH, and conductivity.

Habitat measurements such as canopy cover, and stream width, depth, and discharge were taken according to Washington Department of Ecology protocol for benthic macroinvertebrate sampling (Plotnikoff, 1994). The specific hypotheses tested were that rights-of-way have lower B-IBI scores, warmer water temperature, fewer fish, and a higher percentage of fine particles in streambed gravel.



Solid line indicates county boundaries; dotted line represents watershed boundaries; dot-dash line represents 500 kv powerlines.

Fig. 1. Powerlines follow major river valleys in the Snohomish, Cedar River/Lake Washington, and Green River watersheds within King and Snohomish Counties.

METHODS AND MATERIALS

Study area

The main reason for focusing on the west slope of the central Cascades was because the state's largest capacity powerlines transect two watersheds within King and Snohomish Counties (Fig. 1). The sixteen study sites all lie within the Cascade Ecoregion as established by Omernik and Gallant (1986) for classification of benthic macroinvertebrate communities.

The Green River Watershed spans the southern portion of King County from the Cascade crest in the east to Elliott Bay in downtown Seattle with a total drainage area of 1,440 km^2 (Kerwin and Nelson, 2000). Most of the upper-Green sub-watershed is closed to public access to protect City of Tacoma water supply. Anadromous fish passage has been blocked by Tacoma Public Utilities' water diversion dam at river mile 61 since construction in 1913 (Kerwin and Nelson, 2000). However, a fish ladder is currently under construction to allow fish passage above the dam. Presently, resident cutthroat trout, and transported steelhead, chinook, and coho inhabit the upper-Green and its tributaries. The majority of the land is used for timber production, while public access near the headwaters brings in recreational users for camping, hunting, and off-road vehicle use. The powerline right-of-way in the upper Green River watershed was cleared between 1964 and 1973 and is 202 m wide in most areas (pers. comm. Thompson, 2004).

The Snohomish Basin covers 4,610 km^2 and straddles the border of King and Snohomish counties. The Skykomish and Snoqualmie headwaters begin at the Cascade crest in the east and flow together to form the Snohomish River, which empties into Puget Sound. The Snohomish River supplies municipal water to Everett, southwest Snohomish county, Seattle, Bellevue, and other cities and areas of King County (Pentec Environmental Inc. and NWGIS, 1999). The powerline right-of-way in the upper Skykomish River valley was cleared around 1952, and the lower portion was

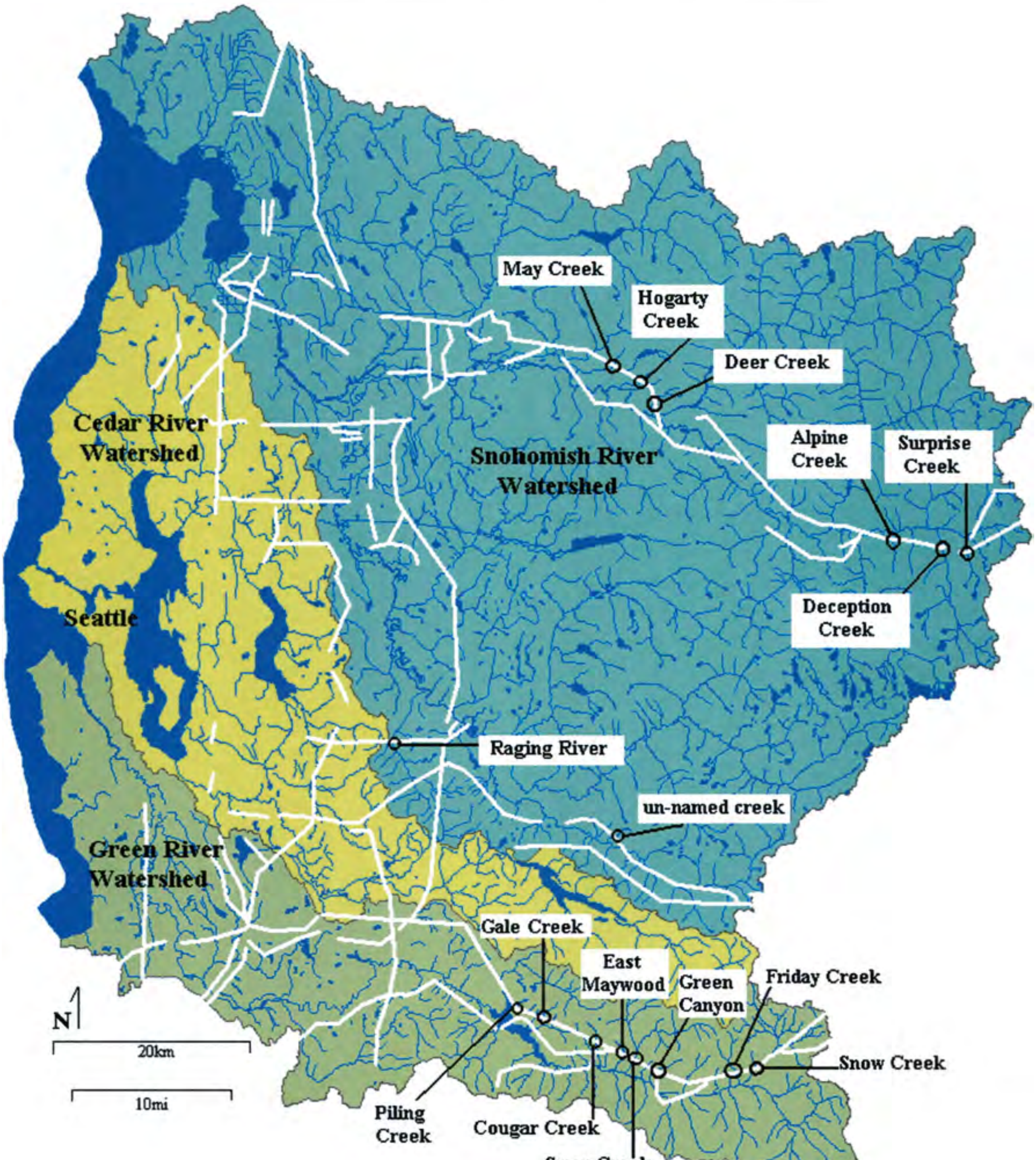


Fig. 2. Map of 16 study sites where high voltage powerline rights-of-way (represented by white lines) intersect small streams in the Western Cascades of Washington.

cleared in 1968; the entire right-of-way is generally 68 m wide (pers. comm. Thompson, 2004).

The Cedar River/Lake Washington watershed was part of the original study design. However, upon examination of the Washington Atlas (e.g. DeLorme, 1995), it was found that each of the potential study sites did not meet the criteria of having minimal human disturbance upstream from the right-of-way mainly because powerlines run through the more urbanized areas.

The term "study site" denotes the paired right-of-way and adjacent upstream habitat. Sampling occurred between July 10, 2003 and September 12, 2003 while streams were experiencing summer low flow conditions. Eight study sites were in the Snohomish Watershed (Fig. 2). Another eight sites were in the upper Green River Watershed, six of which were in the area closed to public access and maintained by Tacoma Public Utilities (TPU) for water supply.

Study design and site selection

To assess and quantify effects of rights-of-way on forested streams, a paired-sample site design was used to compare right-of-way stream sections with their adjacent upstream, undisturbed habitat. To estimate the amount of impact caused by clearing and forest suppression of rights-of-way, the most important metric to measure is the community assemblage of benthic macroinvertebrates as an indicator of human-induced degradation. A second indicator of compromised habitat is the quality of gravel available to spawning salmonids as measured by the percentage of fines (particles smaller than 0.85 mm). Other indicators of the suitability of habitat for salmonids are percentage of canopy cover, water quality, and presence of the salmon and trout themselves.

As rights-of-way parallel major rivers, they intersect each tributary on one side of a river. High voltage distribution lines traverse the Snohomish River and Green River watersheds. Streams were chosen in forested areas at elevations up to 700 m, and potential study sites were selected by using a Washington State Atlas (e.g. DeLorme, 1995). After each location where powerlines intersected streams was identified, only sites in which no more than three minor roads or one highway within a square mile were chosen, and sites that had any upstream disturbances other than minor roads were excluded. This caused rejection of sites in which a stream is likely to be more affected by roads than by the clearing of the right-of-way, and excluded all urban streams.

Sites were chosen by using USGS topographical maps at 1:12,000. Sites were selected based on the following criteria:

- Site provides a valid paired sample in which the right-of-way intersects the stream and the upstream area is within a forested landscape with no human-caused disturbances other than a minimal amount of roads;
- Stream is small enough to wade in, but large enough to host salmonids, which was also determined by using salmonid distribution maps (Pentec Environmental Inc. and NWGIS, 1999; Kerwin and Nelson, 2000);
- Stream has riffles adequate for sampling gravel and benthic macroinvertebrates; and
- Both right-of-way and upstream are accessible by motorized vehicle and a short hike.

Site measurements

To compare the benthic community assemblages between right-of-way and upstream habitat and to regional reference conditions, it was important to follow WADOE protocol for benthic macroinvertebrate sampling. This included calculating the discharge of each stream section, estimating the percentage of canopy cover, characterizing the gravel substrate, and finding the gradient of the stream. The spawning gravel samples were used for the substrate characterization. GIS data and USGS topographical maps were used to find stream gradient.

Sampling of each study site began in a riffle at the downstream end of the right-of-way. First, the location and elevation were obtained with a GPS unit. Then wetted width, bankfull width, and maximum depth in the riffle were measured. After discharge was measured in the riffle, gravel samples were collected from potential spawning areas, and then benthic macroinvertebrates were collected upstream. Densiometer readings were followed by water quality measurements. The spatial and temporal sequence of data collection was designed to minimize disturbances in the riffles from which invertebrates and gravel were collected.

Gravel

Gravel samples were collected from riffle crests in sites that were potential salmonid spawning locations and appeared to be representative of the general conditions of the streambed. The standard method for spawning-gravel sample collecting is outlined in the TFW Ambient Monitoring Protocol (Schuett-Hames et al., 1999). Using the McNeil cylinder (described in the above protocol) for collecting gravel, results in a bucketful of gravel weighing over 40 pounds. It was determined that, for the feasibility of conducting field work for this study, an alternative shovel method is adequate for a comparison of right-of-way and upstream gravel conditions, and a minimum of three samples is required to find the variability in a stream reach (Schuett-Hames et al., 1996; Cederholm, 2003). Samples were rejected in instances where the shovel could not be fully inserted due to armoring, boulders, bedrock, or when the process of insertion caused too much disturbance of substrate to still be representative of the site. Gravel samples were processed using the volumetric method (see: Schuett-Hames et al., 1999). Sieve sizes used were 76.1 mm, 26.9 mm, 3.35 mm, 1.4 mm, 0.85 mm, 0.425 mm, and 0.106 mm. Any particles smaller than 0.106 mm are considered pan silts and were collected in the graduate cylinder at the bottom of the processing basin.

Benthic macroinvertebrates

The in-stream collection method and laboratory processing of the macroinvertebrate samples followed protocols developed by WADOE (see: Plotnikoff and White, 1996; Plotnikoff and Wiseman, 2001). Total area sampled in each stream section was 0.76 m^2. In the lab, the gravel and vegetation matrix containing the macroinvertebrates was randomly removed from a tray until at least 500 organisms were acquired from the surrounding matrix. Organisms from all major orders of freshwater macroinvertebrates were identified to genus, or to the lowest practical taxonomic level, using a dissecting microscope. Taxonomic identification was performed primarily using Merritt and Cummins (1996), with supplemental help from Edmunds (1976), Pennak (1978), McCafferty (1981), and Thorp and Covich (2001).

Table 1. Physical characteristics of the study sites as measured during summer low flow

			Right-of-way		Upstream	
Site	Stream name	Discharge cfs	Wetted width	Elevation	Wetted width	Elevation
1	May Creek	8	6.8	88	5.1	90
2	Piling Creek	1	1.6	362	1.9	408
3	East Maywood	2	2.3	410	1.7	483
4	Smay Creek	47	15.7	428	13.3	471
5	Hogarty Creek	5	3.3	134	1.8	213
6	Deer Creek	3	5.7	106	4.2	140
7	Cougar Creek	1	1.2	504	3.4	534
8	Deception Creek	11	11.2	512	12.2	519
9	Un-named creek	2	2.2	348	3.3	414
10	Green Canyon	8	3.8	433	3.7	463
11	Gale Creek	6	4.8	426	11.4	428
12	Friday Creek	6	2.7	535	5.0	563
13	Snow Creek	13	5.6	584	6.0	597
14	Surprise Creek	34	8.0	656	8.0	660
15	Raging River	20	12.0	193	8.4	208
16	Alpine Creek	9	7.0	366	3.2	367

Discharge is listed in cubic feet per second; wetted width and elevation are listed in meters.

Table 2. No significant differences existed for any water quality parameters measured in the right-of-way and upstream sections

	Right-of-way		Upstream	
Parameter	Mean	95% C.I.	Mean	95% C.I.
Temperature (degrees C)	12.88	±0.90	13.08	±0.94
Dissolved Oxygen (mg/L)	9.59	±0.63	10.03	±0.39
pH	7.30	±0.22	7.18	±0.27
Conductivity	37.61	±8.25	38.74	±7.80

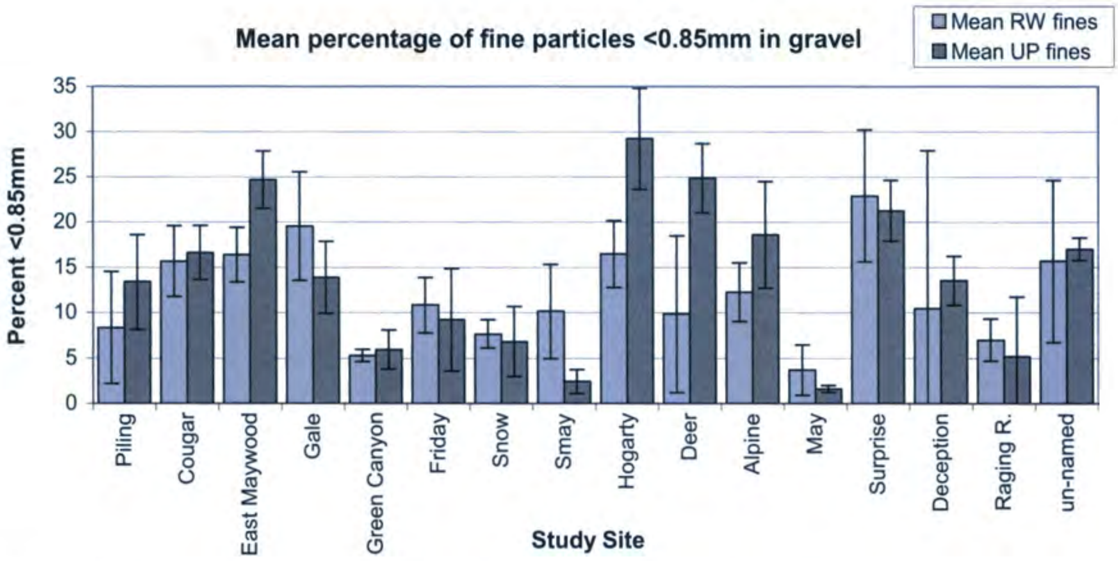
RESULTS

Seeking potential study sites on USGS topographical maps resulted in a list of 24 intersections of power-lines and small streams that could qualify as accessible and valid without being rejected due to too much disturbance from roads or developments. Safety and accessibility issues resulted in the final list of sixteen sites (Table 1).

Eight sites are located in the Snohomish watershed. Three of these, Alpine, Deception, and Surprise Creeks, are tributaries to the Tye River, which flows into South Fork Skykomish River. Another three creeks, Deer, Hogarty, and May, are tributaries to the Skykomish at a lower elevation. Raging River, a tributary to the South Fork Snoqualmie River was accessed from Highway 18. The eighth site is an un-named stream within Olallie State Park near Interstate 90. Another eight sites were found in the Green River watershed. Six of these are in the City of Tacoma's municipal water supply, an area closed to the public and managed by Tacoma Public Utilities. These tributaries to the Green River are the following: Cougar, East Maywood, Gale, Green Canyon, Piling, and Smay Creeks. Two creeks can be accessed above the closed watershed from Forest Road 54; these are Friday and Snow Creeks, which flow into Green River in the headwaters area. Study sites were sampled between July 10 and September 12, 2003. Right-of-way sections were sampled as far downstream as possible within the right-of-way; upstream sections were sampled at a minimum of 200 m upstream from the edge of the right-of-way.

Water quality

Despite the open canopy in the right-of-way sections, mean water temperature was actually slightly, but not significantly, lower than in the upstream counterparts. In fact, none of the water quality parameters showed a significant difference between the right-of-way and upstream sections (Table 2). Water temperatures ranged from a minimum of 10.4 °C in Surprise and Alpine Creeks to a maximum of 17.2 °C in May Creek, and were weakly correlated to elevation ($r^2 = 0.3129$) such that higher elevation streams had lower temperatures. Water temperatures in six streams were above the 14.0 °C critical level for metabolic efficiency for juvenile salmonids, and half of those were beyond the preferred limit of 15 °C. Both dissolved oxygen and pH were generally within target ranges, although the Deer Creek right-of-way had a low dissolved oxygen reading of 5.7 mg/L, and three Skykomish tributaries



Graph bars represent the mean ($n = 3$), and error bars represent the 95% confidence interval.

Fig. 3. Mean percentage of fines was not significantly different between the right-of-way and upstream sections.

had pH values below 6.5. No correlations could be drawn between size of stream, as measured in cfs, and any other habitat data such as water quality, canopy cover, B-IBI score or fish presence.

Canopy

Percentage of canopy cover was greater upstream than in the right-of-way sections at all of the sixteen study sites. The mean percent canopy cover in the rights-of-way was 29% (95% C.I. ± 12.4%); the mean percent canopy cover in the upstream sections was 75% (95% C.I. ± 10.4%). The difference between the means was significant at the $P < 0.0005$ alpha level. Even though the canopy of the rights-of-way was significantly more open, percentage of canopy cover appears to have had no effect on the stream temperatures, which were slightly warmer in the upstream sections.

Gravel

Ninety-six gravel samples were collected and processed—three from each right-of-way and three from each upstream section of the sixteen study sites. The purpose was to detect whether there is a difference in sedimentation between the right-of-way and upstream. The term "fines" refers to the volumetric equivalent of all material collected that was smaller than 0.85 mm. The mean percentage of fines in the 48 right-of-way samples was 12.01% (95% C.I. ± 2.0%); the mean percentage of fines in the 48 upstream samples was 14.01% (95% C.I. ± 2.5%) (Fig. 3). A two-sample t-test assuming equal variances shows no significant difference between mean percentage of fines in the right-of-way and upstream habitats. There was also no significant difference in the mean percentage of pebbles in the >3.35 mm–<26.9 mm size class. The mean percentage of pebbles for the rights-of-way was 33.8% (95% C.I. ± 5%); the mean percentage of pebbles for the upstream sections was 31.7% (95% C.I. ± 6%). The six gravel samples with the highest percentage of fines (Fig. 4) came from upstream sections of Hogarty and Deer Creeks (Fig. 3), two tributaries of the Skykomish River. At these study sites, the powerlines crossed the streams at the base of the hillslope. Gravel samples from Hogarty and Deer Creeks contained soil and root wad material, and were not considered spawning gravel.

No correlation existed between percentage of canopy cover and mean percentage of fines. There was also no correlation between stream discharge and percentage of fines or pebbles. The majority of the 96 samples contained more than the critical value of 11% fines above which salmon eggs tend to become asphyxiated (Fig. 4).

Benthic macroinvertebrates

The purpose of collecting and identifying benthic macroinvertebrates was to be able to calculate a Benthic Index of Biotic Integrity (B-IBI) score for each right-of-way and its corresponding upstream section and then compare the paired scores. As time allowed, specimen identification for eight of the sixteen study sites was completed. Aquatic insects were identified to genus; other invertebrates were identified to class or as low as family when useful in the sensitivity of the index. The minimum possible score in this index is 10 and the maximum is 50. Scores ranged from a low of 30 in Smay Creek to a high of 44 in Gale Creek. No significant difference was detected between the scores for the right-of-way and upstream habitats; the mean score for the right-of-way and upstream sections was 38 for each. There was also no significant difference between right-of-way and upstream habitat for any of the ten parameters used in the index. Half of the upstream

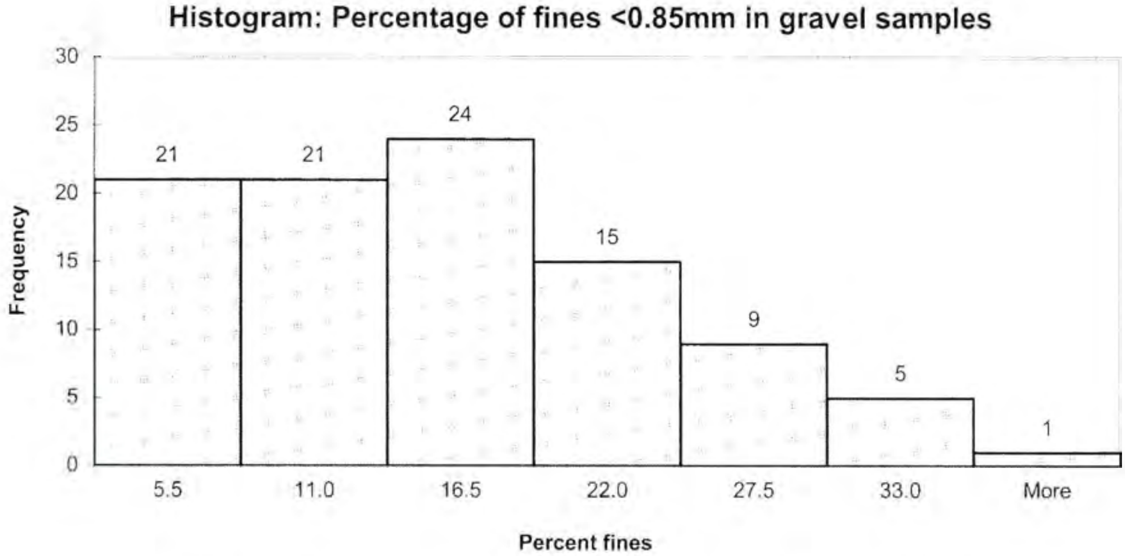


Fig. 4. Histogram: Percentage of fines <0.85 mm in gravel samples. Most of the gravel samples had more than the critical value of 11% fines <0.85 mm.

Table 3. Benthic Index of Biotic Integrity scores for the 8 streams for which identification of the macroinvertebrates was completed

Watershed and stream	B-IBI scores Right-of-way	Upstream
Green		
Cougar	40	42
Gale	40	40
Friday	38	40
Snow	40	34
Smay	32	30
Snohomish		
Hogarty	42	36
May	34	34
Deception	38	40

sections scored lower than their paired right-of-way section. No correlation existed between B-IBI scores and discharge, temperature, or dissolved oxygen. The differences in B-IBI scores reflected the likely effects of differing canopy cover and percentage of fines in gravel, factors that are known to affect the benthos.

Each of the eight streams for which invertebrates were identified scored well for taxa richness. Six classes of invertebrates were collected; these included Acari, Gastropoda, Insecta, Nematomorpha, Oligochaetae, and Turbellaria. Of the five most abundant orders of aquatic insects, the order and its number of representative families are as follows: Coleoptera, 8 families; Diptera, 17 families; Ephemeroptera, 6 families; Plecoptera, 8 families; and Trichoptera, 12 families. The most abundant taxon was the Dipteran family of Chironomidae, which represented 38% of all invertebrates collected and as much as 80% in one of the study sites.

Fish survey

The fish survey was a check for presence or absence of any fish species with the hypothesis that more fish would be detected in the upstream, undisturbed habitat. Fish were witnessed in eleven of the sixteen study sites (Table 3). An equal number of right-of-way and upstream sections had fish present. Species encountered included age-0 coho *O. kisutch*, age-0 and age-1 coastal cutthroat trout *O. clarki*, age-1 and age-2 rainbow trout *O. mykiss*, torrent sculpin *Cottus rhotheus*, and coastrange sculpin *C. aleuticus*. Because collection is not allowed from streams in which endangered bull trout are present, there were a number of occasions in which the fish present could not be identified other than being salmonids.

Mean canopy cover was not significantly different between sites with fish present and sites with fish absent. Dividing the sites into groups with less than and greater than 50% canopy cover also resulted in an equal number of fish occurrences. The mean temperature of the sites in which fish were present was 13.5 °C (95% CI ± 0.9 °C), which was slightly warmer than in the sites where no fish were seen with a mean of 12.3 °C (95% CI ± 0.7 °C), although this was not statistically significant ($P = 0.0677$). Mean percentage of fines in the gravel sampled was slightly lower in areas where fish were detected ($P = 0.1472$), but percentage of pebbles had no bearing on fish presence.

Blockages to fish passage

Two blocking culverts were found among the sixteen study sites using the WDFW Fish Barriers Manual (WDFW, 2000). Two other sites had impediments to fish passage that may or may not be complete blockages. A fifth study site had a gravel road crossing the stream with no culvert, bridge, or other method for vehicles to avoid driving directly through the water.

In the upper Green River watershed, Piling Creek's culvert had an outfall drop of 0.5 m, twice the distance of the 0.24 m critical value for maximum drop.

Table 4. Locations and species of fish occurrences in rights-of-way (rw) and upstream (up) sections

Watershed and stream	Coho	Cutthroat	Rainbow trout	Un-id. salmonid	Coastrange sculpin	Torrent sculpin
Green						
Piling	*rw*		*rw*	*rw, up*		
Cougar*						
E. Maywood				*rw, up*		*up*
Gale						*rw, up*
Green Canyon*						
Friday		*rw, up*				*rw*
Snow*						
Smay				*rw, up*		
Snohomish						
Un-named					*up*	
Hogarty				*rw*	*rw*	
Deer*						
Alpine				*rw*		
May	*up*			*rw*		
Surprise*						
Deception		*up*				
Raging R.	*up*			*rw*		*rw*

*An asterisk indicates a stream in which no fish were seen on the data collection day.

The other blocking culvert was in the un-named creek within Olallie State Park. The problem in this culvert was the 4% slope through the culvert in the middle of a stream with an average gradient less than 1% through the study site. East Maywood Creek has a potential impediment to upstream fish migration. A log across the streambed causes a 0.60 m drop into a wide plunge pool approximately 0.5 m deep. Cougar Creek, also in the Green River watershed, has an old wooden culvert lodged in the streambed upstream from its replacement. Some water flows through the dilapidated structure, which was smashed by a fallen tree, dividing the stream into two potentially impassable watercourses. Since field data were collected during summer low flow, a site visit during higher flows in late fall would be necessary to determine upstream migration passability. During an initial site visit to Alpine Creek, a tributary of Tye River above Skykomish River, it was noted that the powerline access road crossed directly through the stream without any bridge or culvert. Fresh tracks from heavy equipment lined each bank into and out of this salmon-bearing stream.

DISCUSSION

One conclusion that can be drawn from the data is that even though the opened canopy and gravel roads of the rights-of-way do not resemble natural habitat in the Western Cascades, the results do not confirm the hypotheses regarding the suspected degradation. While it was not determined that the rights-of-way are affecting biological integrity of the streams, it appears that each basin is in less than ideal conditions for salmonid habitat. This indicates that there may be some larger force at work over a broader range of the landscape than just the rights-of-way. It is likely that each stream has restabilized from the initial disturbance of right-of-way clearing and powerline installation, which occurred 30–50 years ago. In addition, the rights-of-way are not likely to be any more than a background stress within a greater stress of the whole basin.

The restabilization idea is congruous with several right-of-way studies. Two such studies found no lasting effect of pipeline installation on water quality and stream invertebrates (Young and Mackie, 1991; Blais and Simpson Jr., 1997). Other studies found that aquatic insects and fish populations increase where small areas of canopy had been opened by logging (Murphy and Hall, 1981; Hawkins et al., 1983). In three studies that investigated stream temperatures, two found no difference between right-of-way and undisturbed habitat (Peterson, 1993; Garant et al., 1997), and the other found that while water temperature increased slightly in rights-of-way, cooling groundwater temperatures as well as reclosure of forest canopy both helped to restabilize water temperature at 60–90 m downstream (Day and Carvell, 1979). This study's findings are similar to the aforementioned studies in that the B-IBI scores and fish presence were not significantly different between the right-of-way and upstream sections despite the large difference in canopy cover, nor were water temperatures different between sections. It appears that while many studies of the impacts of timber harvest show cumulative effects on streams in forested habitat, the effects that rights-of-way have are limited to the duration of construction. It is likely that the Central Cascade streams that are intersected by rights-of-way have recovered from the major anthropogenic disturbance and have restabilized to a natural regime.

The specific parameters where the study sites fell below target conditions as listed by Peterson et al. (1992) were water temperature, percentage of fines, and canopy cover. The rights-of-way clearly missed the mark for target canopy cover as only three sites had greater than 60% and none made it to the minimum of 80%. Water temperatures in six streams were above the ideal range for metabolic efficiency for juvenile salmonids at 14 °C. Clearcuts or other landscape features upslope of some study sites may have contributed to warming of the water, as well as the sedimentation in the 10 streams that had more than 13% fines, three of which had more than 20% fines. Logging occurred over much of the Green River watershed from 1880 to 1910 and the City of Tacoma began diverting water for homes and industry in 1913 blocking anadromous fish passage at river mile 61, cutting off 100 miles of mainstem and tributary habitat (Kerwin and Nelson, 2000). Most of the upper Snohomish watershed has been logged and is now in second and third growth stages. These past and present activities are likely the cause of the warmer water temperatures and increased sedimentation. By the time the rights-of-way in the Skykomish River and Green River valleys were cleared in 1952 and 1964, respectively (pers. comm. Thompson, 2004), the much broader scale impacts had already occurred.

The Skykomish River drainage experiences timber harvest, as well as rock quarries, gravel mining, and heavy recreational use with many four-wheel-drive trails (Williams and Ames, 1975). Development and maintenance of the Stevens Pass Ski Resort occurs in the headwaters area of the South Fork Skykomish River. The main activities occurring in the Green River basin that may stress salmonid habitat are timber harvest, off-road vehicle usage, hunting, and camping. Nearly 100% of the upper watershed above Howard Hanson Dam is in forest production (Kerwin and Nelson, 2000), and the headwaters area is open for public recreation. The un-paved gravel access road for the powerline right-of-way is also the main road that logging trucks and recreational traffic use to access spur roads. During field work for this study, it was noted that drive-in campsites suffered from litter, tire tracks through streams, damage to streamside vegetation, as well as trees that had been riddled with bullets to the point of being "shot to death." Anecdotal evidence suggests that at least a few visitors to this area are not applying a "leave no trace" land ethic. If there truly is a difference in biotic integrity between the right-of-way and upstream sections, then the logging and recreational activities that occur over a wider range of the landscape than what the powerlines occupy are likely to mask any effects of the powerline rights-of-way.

Several un-paved gravel roads in the Skykomish watershed experience heavy usage by off-road vehicles. The right-of-way access roads are part of a network of trails for four-wheel drive or single-track vehicles. Several of the spur roads connecting to the right-of-way access road have no bridge or culvert for their stream crossing. During fieldwork for this study, off-road vehicles were witnessed driving through perennial, salmon-bearing streams. Day and Carvell (1979) also noted accelerated bank erosion, sedimentation, and siltation due to vehicles crossing streams and recommended simple bridges or vegetative buffer strips to prevent unnecessary damage from recreational vehicles.

Currently, juvenile chinook, steelhead, and coho are planted in a few streams above Howard Hanson Dam, and projects are underway to allow anadromous fish passage into the upper watershed. However, the WRIA 9 Habitat Limiting Factors Reconnaissance and Assessment Report (Kerwin and Nelson, 2000) identified the Upper Green and Sunday Creek sub-basins as having "not properly functioning" or "at risk" habitat for these populations over a wide range of habitat parameters including riparian habitat, substrate, pools and stream temperature. While timber harvest activities are likely to have the greatest impact on salmonid habitat quality in the upper watershed, it may be important to investigate the impacts of the recreational activities as well. Since the effort and expense of planting fish are expected to return successful spawners, perhaps more effort should be applied to protecting the habitat. Cederholm et al. (1997) recommend a three-step prioritization process to habitat restoration that begins with upslope factors, moves into riparian zones, and lastly focuses on instream habitat. This can be initiated in the public recreational areas in the headwaters region of the Green River Watershed.

A second conclusion that could be drawn from these data is that the methods used were not refined enough or were too short in duration to detect a difference between the effects of past and present logging activities, recreational usage, and creation of rights-of-way. Because of the larger scale effects of logging and recreation on these basins, a more refined analysis would be required to support the hypothesis that rights-of-way degrade Salmonid habitat. One major problem of evaluating effects of land use practices or mitigation measures is the analysis of a small area for a short time, because disturbances that occur over wide areas for long durations have cumulative effects that are not easily measured on a small scale (Ketcheson and Froehlich, 1978). The results may also be an artifact of the approach used to answer the questions.

Two sets of results that may be an artifact of the methods are the percentage of fines in gravel, and the water temperatures. While the gravel samples tell whether the amount of fines is low enough to support egg development in salmon redds, these stream sections may still not have overall adequate gravel sizes to support redd construction. Some locations had exposed bedrock, too much cobble, or a low percentage of pebbles in the streambed. Some sites were not likely to host spawning salmon, but gravel was collected anyway to be able to measure fines and compare right-of-way to upstream sections. The main reason for the upstream gravel samples showing a higher mean percentage of fines seems to be due to the collection of samples in four sites with plant-supporting soil within the sampled riffle area. These sites had more than 20% fines and included two sites in which there were only large cobbles with soil and vegetative material between the cobbles. This contributed to high values in the "pan silts" category. The mean percent fines collected at these two locations was greater than 25%, which raised the total mean for all upstream sections.

Since water temperature was only measured once in each section, this did not provide a comprehensive look at the temperature regimes for the streams. Rather than a snapshot for a right-of-way/upstream comparison, it may have been more useful to plant thermometers that log stream temperature over a longer period such as a minimum of one month of readings. This would provide paired samples of daily fluctuations and a more accurate account of whether the right-of-way has increased water temperature. Turbidity and pH are other measurements that become more accurately descriptive of stream conditions with more measurements over time, rather than single-day measurements. Target ranges for these parameters can be found in MacDonald et al. (1991).

Other habitat factors that could be measured are a comparison of amount of large woody debris, potential for large woody debris recruitment, ratio of pools to riffle habitat, size and frequency of pools, and gravel stability to find probability of scour. Ideal conditions for habitat can be found in Peterson et al. (1992). Relative abundance of exotic invasive plant species was outside of the scope of this study, but is important for overall health of salmon habitat, and is a constant concern in Integrated Vegetation Management of rights-of-way. Areas for further research on the streams in this study should include finding the source of the increased water temperatures in the warmest streams, effects of off-road vehicles on streams with threatened and endangered species, longer duration of water quality measurements, large woody debris presence and potential recruitment, and adequacy of pool habitat. Broader scale research should include measurements of restabilization of stream habitat after disturbances.

CONCLUSION

This study can serve as a baseline inventory for comparisons of salmonid habitat where rights-of-way intersect small streams in the Western Cascades. Results indicate that habitat within the rights-of-way are not severely degraded compared to paired upstream sections, nor are they representative of ideal salmonid habitat conditions. Recommended further research is to perform a similar paired study, perhaps even using the same study sites, but to use a long duration of the water quality measurements, and also to perform a large woody debris inventory and an assessment of potential recruitment from the riparian zone. It is also important to investigate the cumulative effects of fragmentation caused to riparian corridor habitat along the small mountain streams. There is no single parameter that can indicate the productivity or integrity of streams. There is also no place left on Earth that is untouched by human influence. The goal for salmonid habitat assessment is to find the least disturbed, most productive areas, and to then restore disturbed areas with elements that support natural regimes, allowing nature to perpetuate itself.

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REFERENCES

Baddaloo, E.G. 1978. An assessment of effects of pipeline activity in streams in the Durhan and Northumberland Counties of Ontario. Journal of the Canadian Society of Petroleum Geologists 4:2.

Berris, S.N. and R.D. Harr. 1987. Comparative snow accumulation and melt during rainfall in forested and clear-cut plots in the western Cascades of Oregon. Water Resources Research 23(1): 135–142.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pages 191–232 *in* E.O. Salo, and T.W. Cundy, editors. Streamside Management: Forestry and Fishery Interactions. College of Forest Resources, University of Washington, Seattle, Washington.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–138 *in* W.R. Meehan, editor. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, volume Special Publication 19. American Fisheries Society, Bethesda, Maryland.

Blais, D.P. and D.L. Simpson Jr. 1997. The effects of a buried natural gas pipeline on water quality, stream habitat, and biotic populations within high quality cold water streams in upstate New York. Pages 433–441 *in* J.R. Williams, editor. Proceedings of the Sixth International Symposium on Environmental Concerns in Right-of-Way Management. Elsevier Science Ltd. Oxford, New York.

Boss, T.R. 1974. Vegetation study of a powerline right-of-way Whatcom County, Washington. Master's Thesis. Western Washington State College, Bellingham, Washington.

Brosofske, K.D., J. Chen, R.J. Naiman, and J.F. Franklin. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in Western Washington. Ecological Applications 7(4): 1188–1200.

Cameron, D.S., D.J. Leopold, and D.J. Raynal. 1997. Effect of landscape position on plant diversity and richness on electric transmission rights-of-way in New York State. Canadian Journal of Botany 75: 242–251.

Cederholm, C.J. 2003. Dept. of Natural Resources, Personal Communication.

Cederholm, C.J. and coauthors. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17: 947–963.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Pages 38–74 *in* Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest? College of Fisheries, University of Washington. Seattle, Washington.

Cody, W.J., K.L. MacInnes, J. Cayouette, and S. Darbyshire. 2000. Alien and invasive native vascular plants along the Norman Wells pipeline, District of Mackenzie, Northwest Territories. Canadian Field-Naturalist 114(1): 126–137.

Cordone, A.J. and D.W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of a stream. California Fish and Game 47: 189–228.

Day, C.G. and K.L. Carvell. 1979. Effects of power line corridor clearance and maintenance on stream habitat. United States Forest Service, editor Strategies for protection and management of floodplain wetlands and other riparian ecosystems: proceedings of the symposium, December 11–13, 1978, Callaway Gardens, Georgia. Dept. of Agriculture, Forest Service. Washington, D.C.

DeLorme. 1995. Washington Atlas and Gazetteer. DeLorme, Freeport, Maine.

Dominguez, L.G. and C.J. Cederholm. 1996. Rehabilitating stream channels using large woody debris with considerations for salmonid life history and fluvial geomorphologic processes. Pages 545–564 *in* E.E. Knudsen, C.R. Steward, D.D. McDonald, J.E. Williams, and D.W. Reiser, editors. Towards Sustainable Fisheries: Balancing Conservation and Use of Salmon and Steelhead in the Pacific Northwest.

Edmunds, G.F. 1976. The Mayflies of North and Central America. North Central Publishing Co., University of Minnesota, St. Paul.

Finch, K.E. and S.D. Shupe. 1997. Nearly two decades of integrated vegetation management on electric transmission rights-of-way. Pages 67–75 *in* J.R. Williams, editor Proceedings of the Sixth International Symposium on Environmental Concerns in Right-of-Way Management. Elsevier Science Ltd. Oxford, New York.

Galvin, M., K.D. Hoover, and M.L. Avery. 1979. Management of transmission line rights-of-way for fish and wildlife, Volume 1. Performed for Biological Services Program, US Fish and Wildlife Service, FWS/OBS-79/22.

Garant, Y., J. Domingue, and F. Gauthier. 1997. Comparative evaluation of erosion and water temperature in small streams located in powerline rights-of-way and in the upstream undisturbed habitat. Pages 463–467 *in* J.R. Williams, editor Proceedings of the Sixth International Symposium on Environmental Concerns in Right-of-Way Management. Elsevier Science, Ltd. Oxford, New York.

Hawkins, C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the Northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences 40(8): 1173–1185.

Herrington, L.P. and G.M. Heisler. 1973. Microclimate modification due to power transmission rights of way. R. Goodland, editor. Powerlines and the environment; containing proceedings of the Colloquium "Biotic Management Along Power Transmission Rights of Way" held at the American Institute of Biological Sciences annual meeting, Amherst, Massachusetts, June 21, 1973. Cary Arboretum of the New York Botanical Gardens, Millbrook, New York.

Hett, J. and J. Baumert. 1988. Alternative rights-of-way vegetation management comparisons in Western Washington, USA. Pages 109–117 *in* W.R. Byrnes, and H.A. Holt, editors. Proceedings of the Fourth Symposium on Environmental Concerns in Right-of-Way Management. Purdue University, Department of Forestry and Natural Resources. West Lafayette, Indiana.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 5: 55–68.

KCC 21A. 2001. King County Code. King County Comprehensive Plan: Critical Areas.

Kerwin, J. and T.S. Nelson. 2000. Habitat Limiting Factors and Reconnaissance Assessment Report, Green/Duwamish and Central Puget Sound Watersheds (WRIA 9 and Vashon Island). Washington Conservation Commission and the King County Department of Natural Resources.

Ketcheson, G. and H. Froehlich. 1978. Hydrologic factors and environmental impacts of mass soils movements in the Oregon Coast Range. Water Resources Research Institute, Oregon State University, WWR1-56, Corvallis, OR.

Luken, J.O., A.C. Hinton, and D.G. Baker. 1991. Forest edges associated with power-line corridors and implications for corridor siting. Landscape and Urban Planning 20: 315–324.

MacDonald, L.H., A.W. Smart, and R.C. Warner. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. US Environmental Protection Agency, 910/9-91-001, Washington, DC.

McCafferty, W.P. 1981. Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives. Science Books International, Boston.

Merritt, R.W. and K.W. Cummins, editors. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Murphy, M.L. and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38: 137–145.

Naiman, R.J., S.R. Elliott, J.M. Helfield, and T.C. O'Keefe. 2000. Biophysical interactions and the structure and dynamics of riverine ecosystems: the importance of biotic feedbacks. Hydrobiologia 410: 79–86.

Niering, W.A. and R.H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology 55(4): 784–795.

Omernik, J.M., and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency, EPA/600/3-86/033, Corvallis, OR.

Pennak, R.W. 1978. Fresh-water Invertebrates of the United States, 2nd edition. John Wiley & Sons, New York.

Pentec Environmental Inc., and NWGIS. 1999. Snohomish River basin conditions and issues report. The Snohomish River Basin Workgroup, Project No. 293-001.

Peterson, A.M. 1993. Effects of electric transmission rights-of-way on trout in forested headwater streams in New York. North American Journal of Fisheries Management 13: 581–585.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Center for Streamside Studies, University of Washington, F3-92-001, Seattle.

Plotnikoff, R. and J.S. White. 1996. Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington State Department of Ecology. Washington State Department of Ecology, Environmental Assessment Program, No. 96–323, Olympia, WA.

Plotnikoff, R.W. 1994. Instream Biological Assessment Monitoring Protocols: *Benthic Macroinvertebrates*. Washington Department of Ecology, 94-113, Olympia, Washington.

Plotnikoff, R.W. and C. Wiseman. 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams 2001 Revision. Washington Department of Ecology, 01-03-028, Olympia, Washington.

Ramsay, C.A. and R. Parker. 2001. Rights-of-Way Vegetation Management. Cooperative Extension, College of Agriculture and Home Economics, Washington State University, Pullman, Washington.

Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999. TFW Monitoring Program method manual for the salmonid spawning gravel composition survey. Prepared for the WA State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement, TFW AM9-99-001. DNR #101.

Schuett-Hames, D., R. Conrad, A. Pleus, and D. Smith. 1996. Report Field Comparison of the McNeil Sampler with Three Shovel-based Methods Used to Sample Spawning Substrate Composition in Small Streams. Northwest Indian Fisheries Commission, TFW-AM-9-96-005, Olympia, WA.

Thompson, R. 2004. Personal Communication via e-mail.

Thorp, J.H., and A.P. Covich. 2001. Ecology and Classification of North American Freshwater Invertebrates, 2nd edition. Academic Press, San Diego.

WAC 222. 1987. Washington Administrative Code. Forest Practices Rules: Timber Fish and Wildlife Agreement.

WDFW. 2000. Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual. Washington Department of Fish and Wildlife Habitat Program, Environmental Restoration Division, Salmonid Screening, Habitat Enhancement, and Restoration (SSHEAR) Section, Olympia, WA.

Williams, W.R. and J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization. Volume 1 Puget Sound Region. Washington Dept. of Fisheries (now Dept. of Fish and Wildlife), Olympia, WA.

Young, R.J. and G.L. Mackie. 1991. Effect of oil pipeline construction on the benthic invertebrate community structure of Hodgson Creek, Northwest Territories. Canadian Journal of Zoology 69: 2154–2160.

Zallen, M. 1984. Effects of pipeline construction on juveniles and incubating eggs of mountain whitefish (*Prosopium williamsoni*) in the Moyie River, British Columbia. Proceedings of the Third Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi.

BIOGRAPHICAL SKETCH

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Nancy Gleason is completing the Graduate Program in Environmental Studies at The Evergreen State College in Olympia, WA where she also earned a BA. This paper is an abridged version of her Master's Thesis. She has been working as a fish biologist for four years for the Muckleshoot Indian Tribe and the Washington Department of Fish and Wildlife. Her primary research interest is salmon ecology in estuarine ecosystems. She is also exploring the culture-based ecological knowledge and land management practices of Northwest coastal tribes. Her volunteer work includes serving as Secretary on the Board of Directors for the Olympic Coast Alliance, a newly formed organization with the purpose of protecting the Olympic Coast National Marine Sanctuary, its surrounding waters and adjacent uplands.

Investigation of the Potential Effects of Marine Pipelines on Dungeness Crab Movement and Benthic Ecology

Randal D. Glaholt

Concerns have been raised about the potential for marine pipelines to interfere with the movement and ecology of crustaceans such as crabs and lobsters. The results of original research exploring these issues in both laboratory and field settings are presented along with other associated observations. Laboratory investigations suggest that a broad size range Dungeness crab will cross 50 cm (20 inch) concrete coated pipelines but the frequency and percentage of crabs crossing over relatively short time intervals may be dependent on several factors. Field observations of species interactions with a 76 cm (30 inch) diameter pipeline suggest pipes of this size also do not create an impermeable barrier to Dungeness crab or to several other crab species. Pipelines provide Dungeness crab, other invertebrates and vertebrates with foraging opportunities as well as shelter and/or substrate suitable for colonization. Predators of these species do forage near pipelines or take advantage of the structural habitat created by marine pipelines and may offset habitat benefits. Field data suggest that an existing 76 cm diameter marine pipeline may influence adjacent benthic invertebrate diversity and abundance. The effects of a 76 cm diameter pipeline on benthic infauna was most apparent within the first 1 m of the pipeline and diminish at further distances. The observations made in this study, combined with consideration of ecological factors and processes, which occur when a pipe is laid on the seabed, suggest that individual pipelines up to 76 cm diameter are unlikely to have significant impacts on Dungeness crab movement and benthic ecosystems. Measures, which reduce the overall exposure of pipelines or which add surface texture to the pipeline, may reduce what effects do occur; however, such measures are likely not warranted for this purpose alone. In regard to marine pipeline routing, primary emphasis should be associated with ensuring pipeline integrity and avoiding localized, ecologically unique areas. Key elements of a pre- and post-construction monitoring plan to assess potential impacts on Dungeness crab movement involved strategic sampling using commercial crab fishing gear, crab tagging, and a tag return reward program. Pipeline Remotely Operated Vehicle (ROV) video surveys hold some promise as a cost effective tool for monitoring the abundance and distribution of larger sessile or slow moving benthos as indicators of ecological change.

Keywords: Dungeness crab, sea cucumber, sea urchin, flounder, pipelines, benthic ecosystems

INTRODUCTION

Concerns have been periodically raised over the potential for marine pipelines to interfere with the movement and ecology of crustaceans and other benthic marine species. A 1999 proposal by Georgia Strait Crossing Pipeline Limited (GSX) to construct a 67 km (42 mile) long, 53 cm (21 inch) outside diameter (O.D.) natural gas pipeline across the Strait of Georgia between Washington State, USA and Vancouver Island, Canada drew particular attention from the local Dungeness crab (*Cancer magister*) fishery in both western Canada and the United States. As this issue gained attention, concerns were also expressed over other benthic species such as California sea cucumber (*Parastichopus californicus*), green sea urchin (*Stongylocentroides*

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droebachiensis), sanddab (*Citharichthys stigmaeus*), and starry flounder (*Platichthys stellatus*). Over a four-year period, data from laboratory and field investigations were collected and analyzed to better understand the nature of the potential interaction between marine pipelines, Dungeness crab and other benthic faunal components of soft-bottom habitats in the eastern Pacific Ocean. These studies involved laboratory tank tests, sampling of benthic infaunal communities at varying distances perpendicular to an existing large diameter marine pipeline, review of time series underwater marine pipeline monitoring videos and consideration of other incidental observations. Preliminary results of initial investigations into crossing behavior were first presented as part of a more broad-ranging examination of potential pipeline effects on benthic ecology and diversity (Glaholt et al., 2002).

METHODS

Laboratory tank tests

Laboratory experiments were conducted at the Department of Fisheries and Oceans West Vancouver Laboratory, British Columbia in May and June 2001 (Glaholt et al., 2002) and in July, August and November 2002. Two circular, 2.4 m diameter 4,000 liter (L) (1,056 US gallons) and two circular, 3.0 m diameter 6,000 L (1585 US gallons) tanks were used. An approximate 5 cm thick bed of clean sand was used in the bottom of each tank. A 2.1 m long segment of concrete coated, 53 cm (20.9 inch) diameter pipe was used to bisect each tank. Baffles were added to force crabs crossing the pipe to cross on the pipe rather than take advantage of tank–pipe corners. Tanks had an independent flow-through seawater supply and were filled to an approximate 1.2 m depth. An opaque conical fiberglass cover was used to cover each tank. Treatments included use of bare concrete-coated pipe, concrete-coated pipe with chicken wire wrap and concrete-coated pipe with black plastic geotextile mesh (J-Drain, JDR Enterprises Inc. Alpharetta, Georgia). In addition, additional sand was used to simulate the effects of partial burial, as may occur when pipes are laid on very soft substrates, are partially buried by bedload transport, or when they are trenched.

Dungeness crabs, sea cucumbers and green sea urchin were obtained from local commercial fishermen. Speckled sandab and starry flounder were obtained by beach seining. Each crab was identified by placing a number on the anterior of the carapace. Sanddabs and starry flounder were identified by stapling an approximate 10 cm long fishing line to the caudal fin rays and fastening a numbered, 1.5 cm Styrofoam float to the other end. This float was cut in half for smaller sanddabs and flounders.

All individuals were placed in an acclimation tank (flow through tank with no pipe) for 24 hours before being put in anexperimental trial. Treatments were run for either 72 hours or 96 hours. Tanks were covered and monitored at 6-hour intervals. Individuals were assigned at random to each treatment. New individuals were used for each treatment. Sea cucumbers and green urchins were tested together. Speckled sanddabs and starry flounder were tested together. Ten crabs were placed in each 4,000 L tank and fifteen in each 6,000 L tank. Tests involving flatfish were conducted in two 6,000 L tanks (1 control, 1 treatment) with between fifteen and eighteen of each flatfish species used in the test. The duration of experimental exposure was kept to either 72 hours or 96 hours to maximize the opportunity for replication in the time over which laboratory space was available, while at the same time giving individuals what seemed a reasonable time to explore their enclosure and potentially attempt crosssing the pipe. The size of individuals was not significantly different ($P > 0.05$) between treatment and control groups. Adult male Dungeness were significantly larger ($P < 0.05$) than adult female Dungeness (male mean carapace width = 16.7 cm, female mean carapace width = 15.6 cm). Juvenile crabs were also used with a size range of 4.6–10.0 cm (mean = 6.6 cm).

Bazan Bay pipeline benthic infaunal transects

The Bazan Bay pipeline is a 1.58 km (1 mile) long, 76.2 cm (30 inch) diameter, steel, surface-laid sewage pipeline located off Sidney, British Columbia (Fig. 1). The pipe is covered with a smooth coal-tar enamel coating. The pipeline extends from the shoreline to a depth of approximately 30 m (98 feet) below zero chart datum. Sewage from the pipeline is pumped out of the pipeline through a 90 m (295 feet) long, perforated, diffuser section located at the terminal end of the pipeline. The effluent stream is discharged into Sidney Channel and tidal flows tend to run stronger to the north. The pipe traverses an eelgrass bed from the shoreline out to a distance of about 375 m (1230 feet) before grading to a broad, gently-sloping silt and clay, nonvegetated plain. The pipe was installed on October 8, 1999.

The program consisted of taking benthic infauna samples along 10 transects oriented perpendicular to the Bazan Bay pipeline from April 3–6, 2002. Five transects were located on the north side of the pipeline and five transects were located on the south side of the pipeline. Three transects on each side of the pipe were located in 10 m (32.8 feet) water depth in sparse eelgrass habitat and approximately 345 m (1131 feet) seaward of the high water mark. Two transects on each side of the pipe were located in 20 m (65.6 feet) water depth approximately 525 (1722 feet) and 635 m (2083 feet) seaward from the high water mark.

Sample sites were located at 1, 3, 5 and 15 m intervals along each transect. A tape measure was used to establish distance away from the pipeline. At each sample site a 0.25 m^2 quadrat was centered on the specified distance and a photograph taken. A pair

Fig. 1. Dungeness crab climbing the side of 100% exposed 53 cm O.D. concrete-coated pipe segment.

of replicate benthic infauna samples were taken at each quadrat using 15 cm (5.9 inches) long, 10 cm (3.9 inches) diameter, Lexan cylinders, which had 10 cm depth marking on their side. A sample was taken on either side of the quadrat at the appropriate distance. In the case of transect "a" located between transects A and B, a third sample was taken from the centre of the quadrat. The open, pre-labeled cylinders were manually forced into the substrate to 10 cm depth and the top capped. The diver would then excavate down to the bottom of the cylinder and slide a cap on that end.

Eighty-eight sediment cores were collected. A few teaspoons were removed from the length of the core for particle size analysis (PSA). Once the PSA subsamples were removed, the samples were washed. Due to an unanticipated variation in the laboratory screening procedure, samples collected on April 3 and 4, 2002 (transects A and B) were washed on a 1.0 mm screen only (i.e., the 0.5 mm fraction was not retained). Samples collected on April 5 and 6, 2002 (transects a, C and D) were washed on 0.5 mm screen. This variation means that data from transects A and B could not be compared or pooled with data from transects "a," C, and D. The wash water was filtered with a 0.180 mm screen fitted on the intake hose to prevent planktonic organisms or other debris from entering the sample. Fragile organisms were removed by the washing technicians and placed in small labeled vials to prevent them from being damaged by debris in the samples. The vials contained 10% buffered formalin to preserve the organisms.

Washed samples were transferred to 1 litre plastic jars. Depending on sample volume, 25 ml or 50 ml of full-strength buffered formalin was measured with a graduated cylinder and added to each 1 L container. The volume was then brought up to 500 ml or 1 litre, respectively, with seawater. Samples were held in formalin for a minimum of 48 hours to ensure adequate fixation of the organisms. Samples were gently washed using a smaller sieve than that used in the field, to ensure retention of smaller organisms. All material retained on the sieve was returned to the originally labeled plastic jar, and preserved in 70% ethanol. A standard biological stain (Rose Bengal) was added to the samples to facilitate the sorting process.

Small fractions of a sample were placed in a gridded dish and sorted with a dissecting microscope at 10x to 60x magnification. Each dish was sorted until no further organisms or fragments of organisms were recovered (each dish was examined at least twice, regardless of number of organisms recovered). Organisms representing major taxonomic groups (Polychaeta, Mollusca, Crustacea, Nematoda and Other Taxa) were sorted into separate, labeled vials containing 70% ethanol. Fragments of organisms were also placed in separate labeled vials according to major groups. Identifications were performed by qualified taxonomists at Biologica Environmental Services, Sydney, BC. All organisms found in the samples were enumerated and identified to the lowest practical taxonomic level (generally species). If organism fragments were present, only anterior portions were counted, but all fragments were retained. Vials of fragments were checked by the taxonomists to look for the presence of anterior portions of organisms and to ensure fragments had been placed within the correct major group. The list of reference specimens was compared against the list of taxa present in the samples to ensure the completeness of the reference collection.

As part of the identification process, each benthic organism was assigned to an age-class category (adult, immature, or juvenile) based on best professional judgment. Adults and immatures were separated based on relative size and developmental stage of morphological features. Juveniles were defined as the extremely small and undeveloped individuals, compared to the adults and immatures. Reference specimens were stored in 70% ethanol in O-ring sealed cryogenic storage vials, with labels indicating specimen identity, taxonomist, sample number and date identified. Each jar of sorted debris from each sample was examined by the laboratory manager as a quality control (QC) measure. A portion of the sample from each jar was spread in a 9″ × 13″ white pan and examined under a dissecting microscope at 10x magnification. In some cases, the entire sample was examined, because the samples were small. If more than two identifiable organisms were removed the sample was resorted. After the QC was complete, 10% of the samples from each transect and screen size were resorted for quality assurance (QA). Resorted samples were checked again to ensure they passed the spot check.

Particle size analysis

Detailed particle size analysis was performed on one replicate from each sample (40 samples). The analysis was conducted by GeoSea Consulting (Canada) Ltd. A Malvern Mastersizer 2000 laser particle sizer was used for grain size analysis. Dis-aggregation of the sample is achieved by both mechanical stirring and mild ultrasonic dispersion. Statistical differences were examined using One-way and Two-way Analysis Of Variance (ANOVA), t-tests and simple linear regression to determine whether there is a statistically significant ($P < 0.05$) relationship between distance away from the pipe and sediment composition.

Bio-statistical analysis

Statistical analysis was done using SPSS Version 6 & 11, BMDPLR(90). ANOVA, t-tests, Chi-Square Test, Fisher's two-tailed exact test, simple linear regression and logistic regression were used in statistical comparisons. A Levene test for homogeneity of variance was used to determine whether pooled or separate variance estimates would be used in t-tests. A significance level of 0.05 was used. A Bray-Curtis similarity measure (Bray and Curtis, 1957; Ludwig and Reynolds, 1988) was used to provide a more detailed examination of benthic community relative to the pipeline.

RESULTS

Laboratory investigations

May–June 2000

An initial series of laboratory crossing tests of Dungeness crab, conducted from May through June 2000, sought to explore the response of adult male and female Dungeness crabs to 100% exposed concrete-coated pipe and 50% exposed concrete-coated pipe compared with control groups where no pipe was present in the tank (Fig. 1). This experiment showed that within a 72 hour period 82% (54) of commercial sized (>16.5 cm carapace width) male crabs crossed the 100% exposed pipe segment and over 90% (30) crossed the 50% exposed segment (Glaholt et al., 2002). The difference for test males compared to the control males was slightly significant ($P = 0.055$) for the 100% exposed pipe and not significant ($P = 1.00$) for the 50% exposed pipe. The mean number of detected crossings per male crab was 1.83 for the 100% exposed pipe and 2.82 for the 50% exposed pipe compared with 4.16 crossings/crab for the control.

A total of 33% (17) of the female crabs tested crossed the 100% exposed pipe segments over the 72 hour experimental time period while 88% (22) crossed the 50% exposed segments. The difference between the control and test/treatment females was highly significant ($P < 0.00$) for the 100% exposed pipe and not significant ($P = 0.341$) for the 50% exposed pipe. Mean size of females used in this experiment was 14.9 cm carapace width ($n = 103$; SD = 1.13). The mean number of detected crossings per female crab was 0.43 for the 100% exposed pipe and 2.82 for the 50% exposed pipe compared with 3.55 crossings/crab for the control. Frequency and probability of a crab crossing a 100% exposed 53 cm, concrete-coated pipe was significantly ($P < 0.05$) correlated with crab size. For 50% exposed pipe in the same experiment crab size within the size range of crabs examined was not a significant predictor of frequency or probability of crossing.

As reported in Glaholt et al. (2002) both California sea cucumber and green sea urchin exhibited very high degrees of mobility and readily traversed the 53 cm (20 inch) OD concrete-coated pipe (Fig. 2). Sea cucumber exhibited a statistically significant ($P < 0.001$) greater frequency of association with the tank walls than either the sand bottom or concrete-coated pipe while green sea urchins showed a significantly ($P < 0.001$) greater frequency of association with the concrete-coated pipe than the sand bottom or tank walls (in all cases observations were corrected for an equal availability of surface area for

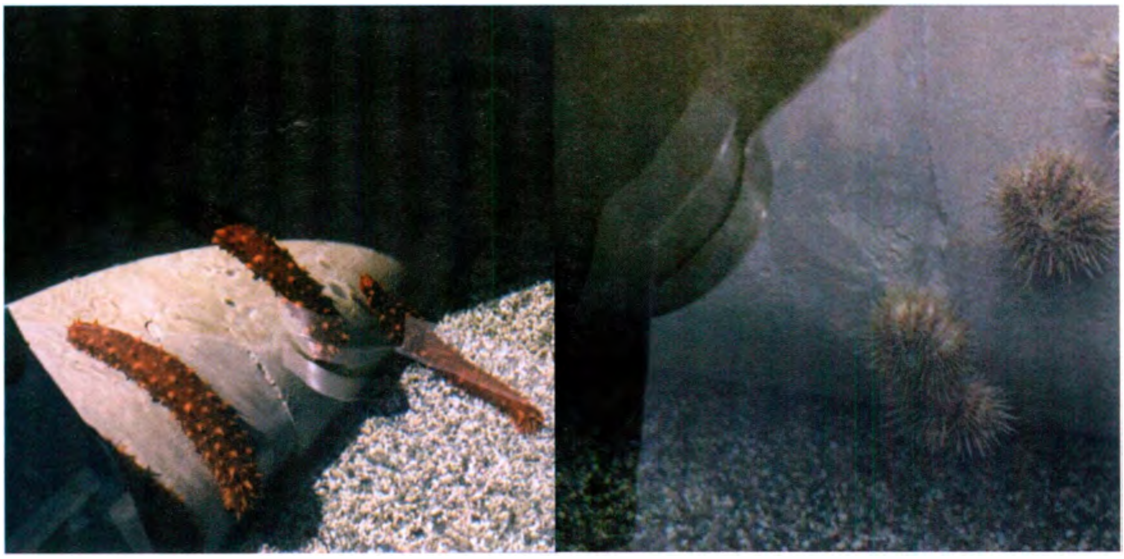

Fig. 2. California sea cucumber and green sea urchin crossing 53 cm concrete-coated pipeline segment.

each of the three options (tank walls, sand bottom and pipe segment). The tube feet associated with echinoderms provide these organisms with a capacity to climb both very smooth and rough surfaces. Organisms, which rely on suction or surface tension for locomotion (e.g., echinoderms, nudibranchs, and snails), are in the absenceof an ecological avoidance response to hard-bottom substrate, likely to have no difficulty traversing a pipe segment.

July–August 2002 laboratory tests

Laboratory experimentation in July–August 2002, sought to explore whether placing plastic or wire mesh wraps around the same concrete-coated pipe would affect crossing response over a 72-hour period. This second phase of experimentation also sought to examine the behavior of smaller juvenile crabs and further explore the effect of 50% exposure and a low sand ramp, which eliminated the overhanging curvature of the bottom laid pipe segment. Results of the July and August 2002 testing are summarized in Tables 1 and 2. For adult males the proportion of crabs crossing 100% exposed concrete-coated pipe with plastic mesh wrap was reduced to 55% while for females the percentage was 34%. With wire wrap the percentage of females crossing was 25%. As summarized above, this compares with 82% for males and 33% for females for unwrapped 100% exposed pipe observed during May–June 2000. The mean number of detected crossings per male crab was 1.025 for the 100% exposed, plastic mesh wrapped pipe (control had 5.31 crossings/crab) compared with the 1.83 crossings detected for 100% exposed pipe with no wrap (control had 4.16 crossings/crab).

The mean number of detected crossings per female crab was 0.6170 for the 100% exposed, plastic mesh wrapped pipe (control had 3.95 crossings/crab) compared with the 0.43 crossings detected for 100% exposed pipe with no wrap (control had 3.55 crossings/crab). When wire mesh wrap was tested on adult females 25% of crabs crossed the 100% exposed pipe, compared with 100% for the control and 34% for the 100% exposed pipe with plastic mesh. The difference between plastic mesh and wire mesh was not significant ($P > 0.05$). Interestingly, only 23.1% of the female crabscrossed a 50% exposed segment of concrete-coated pipe in the July–August 2002 experiment compared with 88% observed during the June–July 2000 experiment. For this same test there was a mean of 0.2308 crossings/female crab compared with 1.76 crossings/female crab observed in June–July 2000. When a shallow sand ramp was being used to eliminate the overhang curvature of the pipe where it contacts the bottom the 7.7% of the test individuals crossed the pipe and the mean number of crossings per crab was 0.7690.

For smaller juvenile male and female crabs (4.6 cm carapace width to 10.0 cm carapace width) 39.1% of the individuals crossed the 100% exposed unwrapped pipe compared to 14.3% for the 100% exposed, mesh wrapped pipe. This pattern was also mirrored in the number of crossings per juvenile crab with 0.7391 crossings/juvenile crab for 100% exposed bare concrete pipe compared with 0.1905 crossings/juvenile crab for 100% exposed plastic mesh wrapped pipeline. The smallest crab to cross the 100% exposed bare concrete pipe was a male with a 5.5 cm carapace width.

Overall it appeared that the activity level of crabs used in the July–August 2002 experiment was lower than that observed during the May–June 2000 experiment. Anecdotal reports from commercial fishermen active in the source area for test crabs indicate that crab harvests typically drop off in the summer months and that Dungeness appear to be subject to high natural adult mortality at this time of year (S. Bowes, pers. comm.).

Table 1. Comparison of the Proportion of Crabs Crossing Concrete-coated Pipeline Segments after 72 Hours for Various Combinations of Pipeline Covering and Substrate Exposure

	Treatment	(*n*)	1	2	3	4	5	6	7	8	Control (*n*)
1	Males, plastic mesh, 100% exp.	40	*55*								100*(35)
2	Males, plastic mesh, 100% exp. attractant (12)	12	50	*50*							100*(13)
3	Females, plastic mesh, 100% exp.	47	34+	34	*34*						98*(44)
4	Females, plastic mesh, 100% exp., attractant	10	0*	0*	0*	*0*					100*(10)
5	Females, wire mesh, 100% exp.	20	25*	25	25	25	*25*				100*(20)
6	Females, bare concrete, shallow ramp (85% exp.)	26	7.7*	7.7*	7.7*	7.7	7.7	*7.7*			95*(22)
8	Females, bare concrete, 50% exp.	13	23.1*	23.1	23.1	23.1	23.1	23.1	*23.1*		100*(13)
8	Juvenile, males, females, plastic mesh, 100% exp.	21	14.3*	14.3*	14.3	14.3	14.3	14.3	14.3	*14.3*	100*(21)
9	Juveniles, males, females, bare concrete, 100% exp.	13	39.1	39.1	39.1	39.1*	39.1	39.1*	39.1	39.1	100*(12)

Notes: Treatment pairs with asterisks are significantly different ($p < 0.05$) from the treatment identified at the top of a given column. + Approaching significance. It should be noted that all crossings represent a minimum number of crossings as there was potential for the experimental subject to have crossed from one side of the tank to the other and gone back undetected. Crossing back and forth was commonly observed.

Table 2. Comparison of Mean Number of Pipeline Crossings/Dungeness Crab after 72 Hours for Various Combinations of Pipeline Covering and Substrate Exposure, July–August 2002

	Treatment	(*n*)	1	2	3	4	5	6	7	8	Control (*n*)
1	Males, plastic mesh, 100% exp.	40	*1.025*								*5.31*
2	Males, plastic mesh, 100% exp. attractant	12	0.7500	*0.750*							*5.15*
3	Females, plastic mesh, 100% exp.	47	0.6170	0.6170	*0.6170*						*3.95*
4	Females, mesh, 100% exp., attractant	10	0.000*	0.000*	0.000*	*0.000*					*5.10*
5	Females, wire mesh, 100% exp.	20	0.4500*	0.4500	0.4500	0.4500*	*0.4500*				*5.65*
6	Females, bare concrete, shallow ramp (85% exp.)	26	0.7690*	0.7690*	0.7690*	0.7690	0.7690	*0.7690*			*4.14*
7	Females, bare concrete, 50% exp.	13	0.2308*	0.2308	0.2308*	0.2308	0.2308	0.2308	*0.2308*		*5.69*
8	Juvenile, males, females, plastic mesh, 100% exp.	21	0.1905*	0.1905	0.1905*	0.1905	0.1905	0.1905	0.1905	*0.1905*	*5.10*
9	Juveniles, males, females, bare concrete, 100% exp.	23	0.7391	0.7391	0.7391	0.7391	0.7391	0.7391*	0.7391	0.7391	*5.00*
	Controls		*5.31**	*5.15**	*3.95**	*5.10**	*5.65**	*4.14**	*5.69**	*5.10**	

Notes: Pairs with asterisks are significantly different ($p < 0.05$) from the treatment identified at the top of a given column. Adult males were significantly larger than adult females. It should be noted that all crossings represent a minimum number of crossings as there was potential for the experimental subject to have crossed from one side of the tank to the other and gone back undetected. Crossing back and forth was commonly observed.

Speckled sanddab and starry flounder

Two replicate runs were conducted, which examined the response of speckled sanddab and starry flounder to a 100% exposed, 53 cm O.D. concrete pipe. There was no significant difference ($P > 0.05$) in the size of the speckled sanddab or starry flounder when comparing individuals used in the control (no pipe) and treatment (Table 3). There was no significantdifference ($P > 0.05$) between the control and treatment for the mean number of pipeline crossings by starry flounder or the proportion of starry flounders, which crossed for either the 72 hour interval or the 96 hour interval. The mean number of pipeline crossings by speckled sanddab was significantly lower than the number of crossings observed in the control tank at 72 hours and at 96 hours; however, there was no significant difference in the proportion of speckled sanddabs crossing the pipe vs. the control tank. Comparing the speckled sanddab with the starry flounder there were no significant differences between the two species were found in the mean number of pipeline crossings or the proportion of individuals crossing at either 72 hours or 96 hours.

All crossings represent a minimum number of crossings, as there was potential for the experimental subject to have crossed from one side of the tank to the

Table 3. Comparison of Pipeline Crossings by Speckled Sanddab and Starry Flounder for a 100% Exposed 53 cm O.D. Concrete-coated Pipe

	Speckled Sanddab	Starry Flounder
n (Control/Treatment)	16/15	15/18
Mean Length Control	26.93	22.76
Mean Length Treatment	24.43	26.97
Mean Number of Control Tank Crossings/fish at 72 hours	4.0*	3.2
Mean Number of Pipeline Crossings/fish at 72 hours	1.5	2.5
Proportion of fish crossing Control tank at 72 hours	93.8	93.3
Proportion of fish crossing the pipeline at 72 hours	73.3	94.4
Mean Number of Control Tank Crossings/fish at 96 hours	6.0*	5.5
Mean Number of Pipeline Crossings/fish at 96 hours	1.6	3.1
Proportion of fish crossing Control tank at 96 hours	100	100
Proportion of fish crossing the pipeline at 96 hours	75	100

Notes: * denotes a significant difference ($P < 0.05$).
n values for 96 hours for control/treatment for speckled sanddab and starry flounder were 8/9 and 8/8 respectively.

Table 4. Comparison of Mean Number of Pipeline Crossings/Crab after 96 Hours for Various Combinations of Pipeline Covering and Burial

	Treatment	(*n*)	1	2	3	4	5	Control (*n*)
1	100% Exposed, unwrapped concrete, males and females (males, females)	49	*0.4286 (0.3200, 0.5417)*					
2	100% Exposed, mesh-wrapped concrete, males and females (males, females)	78	0.7436 (0.6585, 0.8378)	*0.7436 (0.6585, 0.8378)*				
3	1/3 Exposed, unwrapped concrete, males and females (males, females)	79	0.8101* (0.9268*, 0.6842)	0.8101 (0.9268, 0.6842)	*0.8101 (0.9268, 0.6842)*			
4	Control (no pipe), males and females (males, females)	50	5.9* (5.9*, 5.8*)	5.9* (5.9*, 5.8*)	5.9* (5.9*, 5.8*)			*5.9*
5	100% Exposed, unwrapped concrete, females	25	0.16+	0.16*	0.16*	*0.16*		
6	100% Exposed, mesh-wrapped concrete, females	16	1.7500*	1.7500	1.7500*	1.7500*	*1.7500*	
C1	Control (no pipe), females	10	7.3*	7.3*	7.3*	7.3*	7.3*	*7.3*

Notes: Treatment pairs with asterisks are significantly different ($p < 0.05$) from the treatment identified at the top of a given column. + Approaching significance ($P = 0.067$). Statistical comparisons between treatments where genders were mixed with treatments where single gender testing occurred were analyzed on the basis of gender. It should be noted that all crossings represent a minimum number of crossings as there was potential for the experimental subject to have crossed from one side of the tank to the other and gone back undetected. Crossing back and forth was commonly observed.

other and gone back undetected. Crossing back and forth was commonly observed.

November 2002 experiment

Given the variable response of crabs during the experimental period in 2000 and July–August 2002 trials, a decision was made to conduct further tank studies in November of 2002 during a time when local fishermen reported a second phase of increased activity of Dungeness crab in the fishery. The first period of reported heightened activity, in terms of crab harvest was reported to occur from about the end of March to the end of June with typically low success in the fishery during the summer months. Trails were run with the same 53 cm OD diameter concrete-coated pipe as used in previous trials. The treatments were 100% exposed with no mesh wrap, 100% exposed and plastic mesh wrapped and 1/3 exposed with no wrap. All runs were conducted for a 96 hour period. The mean number of pipeline crab crossings and proportion of crabs crossing the pipe treatments over the 96 hour monitoring period is presented in Tables 4 and 5, respectively.

As with previous trials, the number of crossings and proportion of crabs crossing in the control tank in November 2002 was significantly ($P < 0.05$) higher than for treatments involving a pipe segment. Comparing the different pipe treatments where males and females were in the same tank, there were significantly

Table 5. Comparison of Proportion of Crabs Crossing Concrete-coated Pipeline Segments after 96 Hours for Various Combinations of Pipeline Covering and Substrate Exposure

	Treatment	(*n*)	1	2	3	4	5	Control (*n*)
1	100% Exposed, unwrapped concrete, males and females (males, females)	49	*30.6 (24.0, 37.5)*					
2	100% Exposed, mesh-wrapped concrete, males and females (males, females)	78	35.9 (34.1, 37.8)	*35.9 (34.1, 37.8)*				
3	1/3 Exposed, unwrapped concrete, males and females (males, females)	79	46.8+ (56.1*, 36.8)	46.8 (56.1*, 36.8)	*46.8 (56.1, 36.8)*			
4	Control (no pipe), males and females (males, females)	50	100*	100*	100*			*100*
5	100% Exposed, unwrapped concrete, females	25	12.0	12.0*	12.0*	*12.0*		
6	100% Exposed, mesh-wrapped concrete, females	16	68.8*	68.8*	68.8*	68.8*	*68.8*	
C1	Control (no pipe), females	10	100*	100*	100*	100*	100*	*100*

Notes: Treatment pairs with asterisks are significantly different ($p < 0.05$) from the treatment identified at the top of a given column. + Approaching significance ($P = 0.6929$). It should be noted that all crossings represent a minimum number of crossings as there was potential for the experimental subject to have crossed from one side of the tank to the other and gone back undetected. Crossing back and forth was commonly observed.

($P < 0.05$) more crossings and a higher percentage of crabs crossing the treatment in which the pipe was 1/3 buried, than treatments where the pipe was fully exposed or fully exposed, and wrapped in plastic mesh. When the data was separated on the basis of gender, significant effects ($P < 0.05$) were only detected for males. For males, the highest mean number of crossings was for the 1/3 buried pipe, followed by the wrapped pipe and lastly the 100% exposed, bare concrete pipe. For females the mean number of crossings was actually higher for the wrapped pipe, followed by the 1/3 buried pipe and lastly the 100% exposed, bare concrete pipe. Interestingly, the highest mean number of crossings (1.75) and proportion of crabs crossing (68.8%) during this experimental session was during an initial trial run using females alone and wrapped pipe. These values were significantly higher than those for all other treatments with pipe.

Crossing as a function of exposure time

The mean number of pipeline crab crossings and proportion of crab crossing broken out into consecutive 24 hour observation intervals is presented in Tables 6 and 7. There were no significant differences between different 24 hour periods. Logistic regression analysis demonstrated that time, or the experimental duration, was a significant ($P < 0.05$) predictor of the proportion of crabs crossing the pipe treatments. For the laboratory experiments where males and females were combined the shortest predicted time for all crabs to cross was for the 1/3 buried pipe, followed by the mesh-wrapped pipe and lastly the 100% exposed bare concrete pipe. The logistic regressions predicted that, in the laboratory setting it would have taken 13 days for 99% of the crabs to have crossed the 1/3 buried pipe, 19 days for the wrapped pipe, and 32 days for the bare concrete pipe. When the experiment was run using females alone on 100% exposed wrapped pipe and 100% exposed bare pipe the time for 99% crossing was 10 days and 11 days respectively.

Table 6. Mean Number of Crab Pipeline Crossings Per Crab at Four Time Intervals for 100% Exposed Concrete Pipe, 1/3 Buried Concrete Pipe and 100% Expose Mesh-wrapped Concrete Pipe

Treatment* (*n*)	24 hours	48 hours	72 hours	96 hours
100,b,MF (49)	0.1837	0.2857	0.3265	0.4286
180,b,MF (79)	0.1772	0.4430	0.6203	0.8101
100,w,MF (78)	0.1923	0.3718	0.5513	0.7436
100,b,F (25)	0.0000	0.4000	0.1200	0.1600
100,w,F (16)	0.3125	0.5000	1.1250	1.7500

*100,b,MF = 100% exposed, bare concrete pipe, males and females together; 180,b,MF = 1/3 buried, bare concrete pipe, males and females together; 100,w,MF = 100% exposed, bare concrete pipe, males and females together; 100,b,F = 100% exposed, bare concrete pipe, females alone.

Table 7. Percentage of Crabs Crossing a Pipeline at Four Time Intervals for 100% Exposed Concrete Pipe, 1/3 Buried Concrete Pipe and 100% Expose Mesh-wrapped Concrete Pipe

Treatment* (*n*)	24 hours	48 hours	72 hours	96 hours
100,b,MF (49)	18.4%	26.5%	26.5%	30.6%
180,b,MF (79)	15.2%	31.6%	43.0%	46.8%
100,w,MF (78)	16.7%	24.4%	33.3%	35.9%
100,b,F (25)	0.0%	4.0%	12.0%	12.0%
100,w,F (16)	31.3%	31.3%	62.5%	68.8%

*100,b,MF = 100% exposed, bare concrete pipe, males and females together; 180,b,MF = 1/3 buried, bare concrete pipe, males and females together; 100,w,MF = 100% exposed, bare concrete pipe, males and females together; 100,b,F = 100% exposed, bare concrete pipe, females alone.

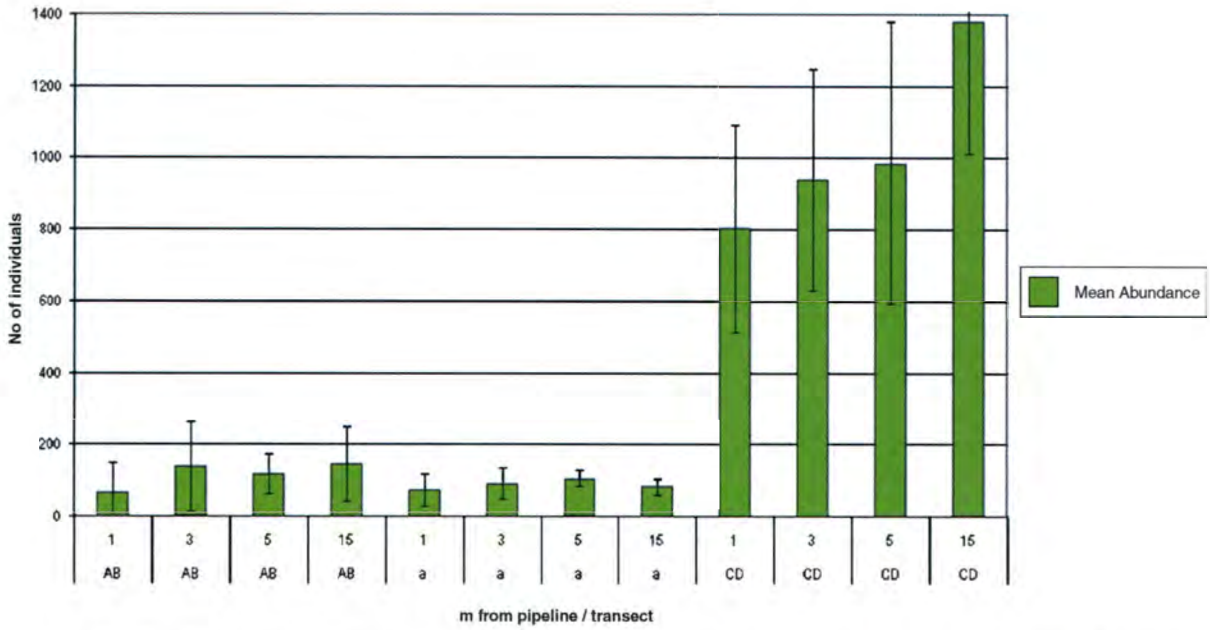

Fig. 3. Mean abundance of infauna relative for different transects and at different distances perpendicular to the Bazan Bay pipeline.

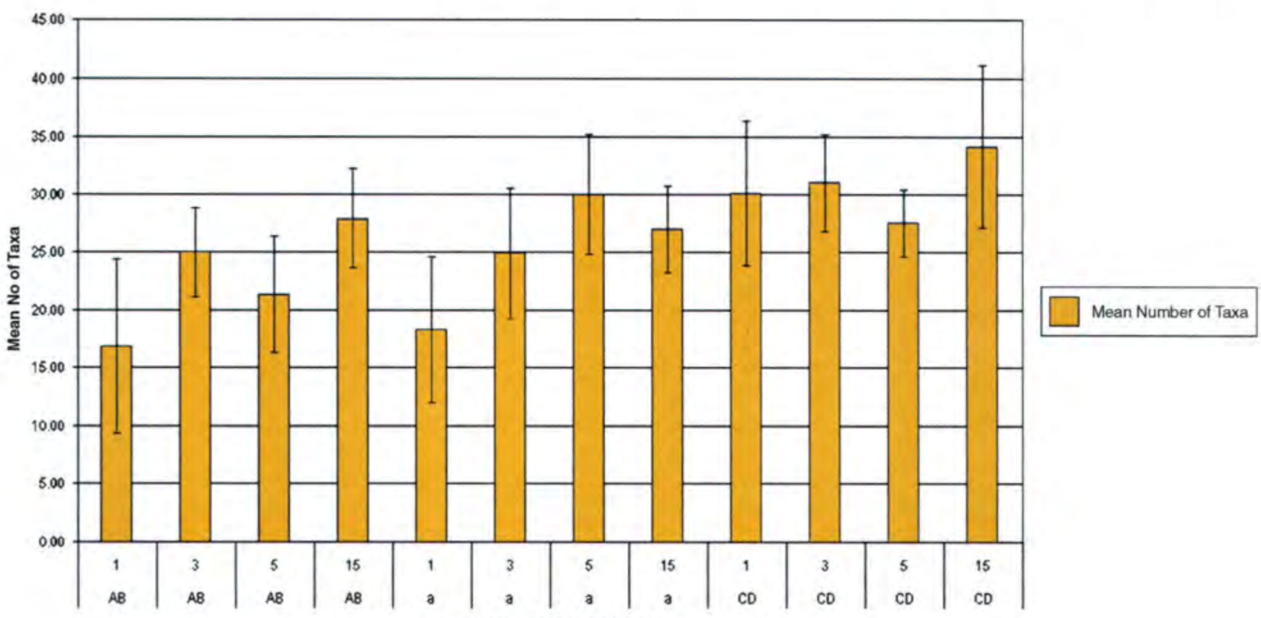

Fig. 4. Mean number of taxa of infauna relative for different transects and at different distances perpendicular to the Bazan Bay pipeline.

Bazan Bay pipeline benthic infaunal transects

A total of 88 benthic infaunal core samples were taken in close proximity to the 76 cm (30″) O.D. Bazan Bay pipeline. Aggregating all samples, a total of 256 taxa were represented, and included 185 identified to species. The 32 core sample collected from the four nearshore, shallower transects in sparse eelgrass (Transects A north and south and B north and south; sieved at 1 mm) produced 3,758 individuals or an average of 14,960 individuals/m^2 (0.15 individuals/cm^3) representing 145 taxa (including 105 taxa identified to species). The 24 core samples collected along Transect "a" north and south, located approximately 10 m (32.8 feet) between Transects A and B and sieved at 0.5 mm, produced a total of 2,011 individuals or an average of 10,674 individulas/m^2 (0.11 individuals/cm^3) representing 109 taxa (including 82 taxa identified to species). The 32 core samples collected along the four deeper transect pairs (C and D north and south) also sieved at 0.5 mm produced 31,875 individuals or an average of 126,890 individuals/m^2 (1.27 individuals/cm^3) representing 176 taxa (including 129 taxa identified to species).

The mean number of individuals and mean number of taxa observed at each sample station for the different transect pairs is presented in Figs. 3 and 4. Data for transects A and B could not be directly compared with data for transects "a", C or D as samples from Transects A and B were sieved at 1.0 mm while remaining three were sieved at 0.5 mm.

Influence distance from pipeline on number of taxa and individuals

Pooling data from all transects revealed that distance was a significant predictor for the number of taxa (t[86] = 3.330, $P = 0.001$, R Square = 0.114) and could be expressed by the following formula: Y = 23.616 + 0.443(d) where Y = the number of taxa or species richness and d = the distance in meters. The R Square in this case is low with roughly 89% of the variation in number of taxa due to other factors, which are not accounted for in the model. Using a two-way ANOVA it was determined that the effect of distance on number of taxa and number of individuals significantly ($P < 0.05$) varied depending on which transect or transect pairs were considered. Distance was a significant predictor of the number of taxa for two combined shallower habitats in sparse eelgrass (t[30] = 3.180, $P = 0.003$, R Square = 0.252) and could be expressed by the following formula: Y = 19.154 + 0.605 (d). Distance from the pipeline was not a significant ($P > 0.05$) predictor of number of taxa (Y) for the two deeper habitats in open silt/mud bottom.

Where data from all transects were pooled, distance was not a significant predictor of the number of individuals; Where?? (t[86] = 1.590, $P = 0.115$, R Square = 0.029, # Individs = 345.117 + 15.848(d)). However, distance was a significant predictor of the number of individuals for the two deeper habitats in open silt/mud bottom (t[30] = 3.639, $P = 0.001$, R Square = 0.306) and could be expressed by the following formula I = 789.044 + 39.717(d) where I = the number of individuals. Distance was not a significant predictor (t(30) = 1.255, $P = 0.219$) of number of individuals for the two combined shallower habitats in sparse eelgrass.

Multiple pair-wise comparison of the mean number of individuals at different distances from the pipeline revealed significant differences ($P = 0.008$; $n = 56$) only for comparisons of sites 1 m from the pipe with sites 15 m from the pipe, no other pair-wise comparisons were significantly different. The number of taxa was also only significantly different ($P = 0.023$, $n = 56$) for the comparison of the 1 m sites with the 15 m sites.

Influence of distance from pipeline on community composition

Community analysis examining the similarity in species composition of the various sites using a Bray-Curtis similarity measure (Bray and Curtis, 1957; Ludwig and Reynolds, 1988) revealed that the shallower eelgrass habitat had a significantly different species composition than the deeper open silt/mud habitat. The sites 1 m distant from the pipeline in shallower sparse eelgrass habitat both north and south of the pipeline had significantly different ($P < 0.05$) species composition than all other distance sites in this habitat. Other differences in community composition were not apparent using the analytical techniques employed.

Influence of distance from pipeline on the abundance of Crustacea, Polychaetes, Mollusca, Nematoda and other infauna phyla

Samples from shallow, sparse eelgrass habitat, which were sieved at 1.0 mm, revealed a significant correlation (t[14] = 2.581, $P = 0.022$, R Square = 0.322) between distance and number of individuals for "Other Phyla" and could be expressed by the following formula: Y = 77.200 + 136.025(d) where Y = the mean number of "Other Phyla" and "d" = distance from the pipeline in meters. On the other hand samples from this same habitat type, which were sieved at 0.5 mm, revealed significant relationships (t[22] = 3.475, $P = 0.002$, R Square = 0.354) between distance and the number of Polychaetes and could be expressed by the following formula: Y = 21.667 + 7.033(d) where Y = the mean number of Polychaetes and "d" = distance from the pipeline in meters. Distance was not a significant predictor of abundance for the other phyletic groupings.

When data from the deeper, open silt/mud habitat were analyzed, distance was found to be a significant predictor (t[14] = 2.269, $P = 0.040$, R Square = 0.269) of abundance for Polychaetes (expressed by the formula: Y = 43.875 + 8.75(d)) as well as a significant predictor (t[14] = 3.016, R Square = 0.394) for the number of Crustacea (expressed by the following formula: Y = 568.875 + 207.775(d)). Distance was not a significant ($P > 0.05$) predictor of abundance for any of the other phyla in the deeper silt/mud habitat.

Pooling data for the two habitats revealed that distance was a significant but weak predictor for the number of polychaetes (t[86] = 2.177, $P = 0.032$, R Square = 0.0052) but not for the other phyletic groups examined.

Two way ANOVA revealed that there were significant ($P < 0.05$) differences in the mean number of individuals for Crustacea and Mollusca at all distances when comparing the shallow, sparse eelgrass habitat with the deeper open silt/mud habitat. Significant differences between the two habitats were not detected for the other phyletic groups examined.

When the data sets were split on the basis of "direction," i.e. testing observations on the north side of the pipe and south side of the pipe independently it was determined that distance was a significant predictor of the mean number of individuals for Crustacea ($P = 0.0234$), Polychaetes ($P = 0.0159$), Mollusca ($P = 0.0312$) and Other Phyla ($P = 0.0021$) on the north side of the pipe but not on the south side of the pipe. Distance was not a significant predictor of the mean number of Nematoda on either the north ($P = 0.6195$) or south ($P = 0.7593$) side of the pipeline.

The strongest relationship observed was for the aggregation of "Other Phyla" (t[14] = 3.767, R Square = 0.50335) on the north side, where 50% of the variation in mean number of individuals could be explained by distance and could be expressed by the following formula: $Y = -49.575 + 121.54(d)$ where Y is the mean number of individuals and "d" is the distance in meters from the pipeline.

Influence of distance from pipeline on three common benthic infauna species

The total number of individuals for most taxa at any given sample site was less typically than 20 and in most cases represented by fewer than 10 individuals. Anomalies to this general pattern were conspicuous for *Ampelisca pugetica*, *Leptochelia savignyi*, and *Dipolydora cardalia*. Pooled transect data from shallow eelgrass habitat and deeper open silt/mud bottom habitats as well as individual transect data suggested that distance from the pipeline was not a significant predictor of the number of *D. cardalia* or *L. savignyi* ($P > 0.05$). Distance was a slightly significant predictor of the abundance of *A. pugetica* when data from shallow and deep transects were pooled (t[46] = 2.018, $P = 0.049$, R Square = 0.081). Distance was a highly significant ($P < 0.05$) predictor of the abundance of *A. pugetica* when linear regression analysis was performed on individual transect data. For the deepest open silt/mud habitat site approximately 43% of the variation in *A. pugetica* could be explained by distance from the pipeline (t[14] = 3.246, $P = 0.006$, R Square = 0.429) and could be expressed by the formula $N = 491.170 + 36.274(d)$. Distance was also a significant predictor (t[14] = 2.827, $P = 0.013$, R Square = 0.363) of *A. pugetica* abundance at the second deepest transect in open silt/mud bottom as well as for a transect in shallow, sparse eelgrass habitat (t[14] = 2.540, $P = 0.013$, R Square = 0.315).

Where data from shallow sparse eelgrass habitat were pooled with data from deeper open silt/mud habitat multiple pair-wise comparison of the mean number of individuals for each of these three more abundant species at different distances from the pipeline did not reveal any significant differences in the mean number of individuals ($P > 0.05$) between distance pairs despite significant between groups differences for each species based on ANOVA. Where these data were separated on the basis of habitat type, significant differences were only detected for *A. pugetica* when comparing 1 and 15 m samples sites ($P = 0.008$) and 3 m and 15 m sample sites $P = 0.047$) in the open deeper water silt/mud habitats. No significant ($P > 0.05$) distance pair-wise comparisons were detected for the shallow sparse eelgrass habitats.

Influence of distance from pipeline on benthic sediment composition

Mean sediment grain size, %sand and %mud, were not significantly correlated with distance from the pipeline ($P > 0.05$). There were significant differences in sediment grain size, %sand and %mud depending on which side of the pipe was involved. Mean grain size and % mud were significantly ($P < 0.05$) lower on the north side while % sand was higher ($P < 0.05$). Collectively, samples taken in 10 m depth in sparse eelgrass habitat were not significantly different than samples taken at 20 m in open soft-bottom habitat.

Incidental observations of benthic organisms in relations to marine pipelines

During the course of the sample collection and associated video reconnaissance at the 76 cm diameter, 1.5 km long Bazan Bay pipeline, Dungeness crab (*C. magister*) and other crab species (*Telmessus cheiragonus*, *Cancer gracilis*, *Cancer productus*, *Chlorilia longipes*, *Oregonia gracilis*, *Pugettia producta*, *Pugettia richii*), shrimp (*Neotrypaea californiensis*, *Pandalus danae*, *Heptacarpus brevirostris*), spot prawn (*Pandalus platyceros*), kelp fleas (*Parapleustes pugettensis*), nudibranchs (*Dirona albolineata*, *Triopha catalinae*, *Diaulula sandiegenesis*), and starfish (*Pycnopodia helianthoides*, *Pisaster ochraceus*) were all observed on the Bazan Bay pipeline, suggesting that the pipeline was being traversed by these species. Dungeness crab were observed feeding on epiphytic algae growing on the pipe exterior as well as actively crossing the pipe. Drift algae piled up against the pipe in places may have also been serving to attract some species to the pipe. Dungeness crab were observed buried in substrate immediately adjacent to the pipe as if taking advantage of the additional security it may have provided; however, this species was also noted buried into sediments up to the outer limit of the 15 m sample transect length perpendicular to the pipeline. Within three years of construction the 76 cm (30 inch) diameter Bazan Bay pipe had out to at least 20 m (65.6 feet) water depth, become extensively colonized by sessile flora and fauna normally associated with hard-bottom benthic habitats. Marine algae observed growing on the pipe included broadleaf kelp (*Alaria marginata*), sea staghorn (*Codium fragile*), sea hair (*Enteromorpha intestinalis*), and wireweed (*Sargassum muticum*). Attached fauna included bread crumb sponge (*Halichondria* sp.), yellow encrusting sponge (*Myxilla lacunose*), velvety red sponge (*Ophlitaspongia pennata*), wrinkled sea squirt (*Pyura haustor*) green false jingle shell (*Pododesmus macrochisma*), brooding anemone (*Epiactus prolifera*) and various unidentified hydroids and bryozoans. Demersal fish observed in close association with the pipe were Pacific sanddab (*Citharichtys sordidus*), tube snout (*Aulorhynchus flavidus*), longfin sculpin (*Jordania zonope*) and other unidentified sculpins.

Review of time series underwater video surveys of a pair of 25.4 cm (10 inch) diameter 46 km (28 mile) long gas pipelines crossing Georgia Straight (Vancouver Island Pipeline) taken at three intervals over the first ten year period following construction revealed that crustaceans such as box crab (*Lopholithodes* sp.), red rock crab (*Cancer productus*) and California sea cucumber (*Parastichopus californicus*) were actively crossing the pipes. Crustacea such as prawns and shrimp appeared to be strongly attracted to habitat created by the exposed pipe, particularly where it was not largely buried in sediment. Sites where span correction involved the use of concrete mattresses draped over the pipe provided particularly attractive habitat for prawns as well as some suitability for giant pacific octopus. Pipe colonization by sessile species normally associated with hard-bottom benthic habitats such as tube worms (*Serpula vermicularis*) and giant plumose anemones (*Metrideum giganteum*), hydroids and sponges had begun within one year of construction. Species such as cloud sponge (*Aphrocallistes vastus*) were well established on pipe segments within ten years. While conspicuous concentrations of fish were not observed during any of the three Remotely Operated Vehicle (ROV) video surveys demersal species observed in close association with the pipes and span correction elements were ratfish (*Hydrolagus colliei*), yelloweye rockfish (*Sebastes ruberrimus*), quillback rockfish (*Sebastes maliger*) cabazon (*Scorpaenichthys marmoratus*) and lingcod (*Ophiodon elongates*).

It was also apparent that in soft-bottom habitats that some segments of the Vancouver Island Pipeline had settled into the soft-bottom substrate in excess of half the pipe depth within the first year. Windrows of current transported sediments were also note to accumulate on other pipe segments forming a ramp on one side of the pipes while in other instances the pipe remained either fully exposed and completely resting on the bottom or had either stable or active free span segments. Rapid submergence of pipeline into benthic habitats with soft marine sediments has also been anecdotally observed in the Gulf of Mexico and elsewhere (B. Exley pers. comm.).

DISCUSSION

Laboratory investigations into the response of Dungeness crab to pipelines suggest that a broad size range of Dungeness crab will cross fully exposed concrete-coated pipes up to at least 50 cm diameter although the number of individuals crossing and frequency of crossing over relatively short time intervals in the laboratory appears to be influenced by the amount of pipe exposed above the surface, surface roughness, gender interaction and possibly overall seasonal activity levels. Other benthic species studied in the laboratory setting (starry flounder, speckled sanddab, California sea cucumber, and green sea urchin) also demonstrated a willingness to cross a 50 cm concrete-coated pipeline. The tendency for marine pipelines to either settle into soft-bottom substrates and or have frequent free span conditions on more irregular hard seabed habitat as well as their propensity for rapid colonization by epibionts further tends to mitigate potential physical barrier effects. Recent attention has been paid to the ability of crustacea such as lobster to use electromagnetic fields for navigation (Boles and Lohman, 2003). These findings have also sparked additional concern that metallic objects newly placed on the seabed may result in disruption of crustacean movement. While this possibility has not been experimentally examined, it is unlikely that an individual pipeline would disrupt the Earth's magnetic signature. Electromagnetic telemetry is routinely used on crustaceans to map movement patterns, seemingly without interference. To the extent that metallic objects are relevant to crustacean movement, seabed objects including pipelines should be incorporated into the ambient electromagnetic landscape to which newly settled crustacean larvae would adapt.

While the potential for localized pipeline barrier effects may exist, incidental field observations of species interactions with a 76 cm diameter pipeline suggest pipes of this size also do not create an impermeable barrier to commercially valuable species such as Dungeness crab or to several other mobile benthic invertebrate and vertebrate marine species. Pipelines create ecological conditions that provide some crustacea, other invertebrates and vertebrates with foraging opportunities as well as shelter or substrate suitable for colonization. Species, which will prey on marine invertebrates, do forage near pipelines and take advantage of the structural habitat created by marine pipelines, and this may neutralize the potential for pipelines to result in a net increase in productivity of some benthic invertebrate populations.

The analysis of data from benthic infaunal core samples taken at varying distances perpendicular to an existing 76 cm diameter marine pipeline suggests that pipelines may have an influence on benthic infaunal diversity or species richness as well as the total number of individuals for certain species and phyletic assemblages. Where a significant relationship was detected the typical response was for there to be increasing diversity and or abundance with increasing distance from the pipeline. Effects vary with habitat and can be more discernible on one side of a pipeline than the other. This effect may be related to observed differences between north and south sides of the pipe in sediment composition, which in turn may be related to physical and possibly biological processes. Overall, the effects of a 76 cm diameter pipeline on benthic infaunal communities appear to be localized and where they are detectable, most apparent within the first 1 m of the pipeline though more subtle effects may extend beyond this. These very localized effects on infauna mirror effects on infauna also reported by others in relation to large complex artificial reef structures (Davis et al., 1982; Ambrose and Anderson, 1990). Davis et al. (1982) did observe some more far ranging effects on macrobenthos such as sea pens (*Stylatula elongata*), which were attributed to foraging by reef-associated fish.

Drift algae and other debris tended to accumulate immediately beside the marine pipeline examined at Bazan Bay and may have resulted in increased biological oxygen demand. This phenomenon, along with the development of quiescent pools or strips on the dominant down-stream side of the pipelines would tend to increase oxygen consumption and block the sediment surface from oxygen replenishment by currents in the overlying water. This may explain why several of the normally dominant taxa were absent or rare in the samples taken at 1 m distant to the pipeline. Overall it is suggested that effects proximate to the pipeline are the result of variation in species interactions (e.g., crab foraging, fish predation) combined with hydrodynamic pipeline effects (e.g., eddying and turbulence) as well as the effect of organic "windrows." The potential for non-linear, distance-related effects may exist. The relatively low correlation coefficients associated with significant distance effects at the site and distances reported in this study suggest that other non-pipeline related phenomenon are at least as important as pipeline presence in determining patterns of species diversity and abundance in soft-bottom benthic communities.

Implications for marine pipeline mitigation

The observations made in the course of laboratory and field investigations reported in this study combined with consideration of widespread planktonic dispersal and recruitment in marine organisms, the physical size and simple geometry of pipelines as well as the processes which occur when a pipe is laid on the seabed (e.g., settlement, windrowing, trench sloughing and infilling, free spans) suggest that individual pipelines up to 76 cm diameter are unlikely to have a significant impact on Dungeness crab movement and their associated benthic ecosystem. This; however, does not consider the ecological implications of cumulative effects associated with high densities of marine pipelines or the potential consequence of marine pipeline rupture.

While long-term monitoring studies of pipelines in relation to crustacean movement have not been undertaken or completed, it is the author's opinion that there is currently insufficient evidence to justify the expense and impact associated with pipeline burial solely as a means of facilitating crustacean movement or to reduce the ecological impacts of individual pipelines, particularly on smaller pipelines. Measures, which do reduce the overall exposure of pipelines or which add surface texture to the pipeline, will reduce what effects do occur. In regard to marine pipeline routing, primary emphasis should be associated with ensuring pipeline integrity and avoiding ecologically unique areas.

Barrier and ecological effect monitoring studies

The impetus for the studies described in this research was driven in part by the expressed concern and uncertainty of commercial crab fishers, resource managers and public interests in regard to the GSX Project. As part of the pre and post construction monitoring commitments made by the project proponent, a large scale Dungeness crab monitoring program was designed and implemented. Key elements of this program involved strategic sampling using commercial crab fishing gear, tagging of crabs on either side of the proposed pipeline right-of-way and at a number of reference sites, as well as a tag return reward program ($10/tag). All commercial crab fishers were provided with details of the program, instructions for reporting, and data notebooks for recording their data. Notices to the public were placed in local marinas. During the first twelve months of the program a total of 28,838 crabs were handled, 6,353 crabs were tagged and released, and 1,876 (29.5%) tags were returned (1,871 returned by commercial fishers and 5 by recreational fishers). A total of 15 crab boats provided tag returns from the commercial fishery. The project was suspended as a result of business decisions. The program experienced relatively high participation rates from local commercial fishers. A highly experienced local commercial crab fisherman was contracted to assist with the deployment of all research gear. While some fishermen refused to record data associated with tagged crabs, most were compliant.

Additional studies were planned by GSX to facilitate monitoring of "artificial reef" effects attributable to the pipeline through use of stratified ROV video surveys. These surveys were to be combined with periodic marine pipeline surveillance. Based on the results of previous pipeline ROV biological surveys this technique holds some promise for monitoring the abundance and distribution of larger sessile or slow moving benthos such as large crabs, starfish, some sea cucumbers, sea anemones, sea pens, large sponges and other species as indicators of ecological change. The benefit is benefit the correct word here? of repeat sampling of benthic infaunal communities pre- and post-pipeline disturbance is time consuming and costly, and has inherent challenges associated with precision location of sample sites. The effort and accuracy required for infaunal sampling in this case needs to be weighed against the small scale at which effects appear evident, as shown by the Bazan Bay investigation.

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REFERENCES

Ambrose, R.F. and T.W. Anderson. 1990. Influence of an artificial reef on the surrounding infaunal community. Marine Biology 107: 41–52.

Boles, L.C. and K.J. Lohman. 2003. True navigation and magnetic maps in spiny lobster. Nature 421: 60–63.

Bowes, S. Personal communication. Commercial Crab Fisherman, Sidney, BC.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349.

Burd, B.J., A. Nemec, and R.O. Brinkhurst. 1990. The development and application of analytical methods in benthic marine infaunal studies. Advances in Marine Biology. 26: 169–247.

Davis, N., G.R. Blaricom, and P.K. Dayton. 1982. Man-made structures on marine sediments: effects on adjacent benthic communities. Marine Biology 70: 95–303.

Exley, B. Personal communication. Williams Gas Pipeline, Houston, TX.

Glaholt, R.G., M. Nunas, and S. Ong. 2002. An investigation into the influence of marine pipelines and cables on benthic ecology and biodiversity. In *Environmental Concerns and Rights-of-Way Management: Seventh International Symposium.*J.W. Goodrich-Mahoney, D.F. Mutrie and C.A. Guild (eds). Elsevier Science Ltd. pp 765–775.

Ludwig, J.A. and J.F. Reynolds. 1988. Polar Ordination. Chapter 18. In *Statistical Ecology*. J. Wiley and Sons. Toronto. pp 211–222.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry. 1st Edition. W.H. Freeman and Company, San Francisco.

BIOGRAPHICAL SKETCH

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Investigations into Gas Pipeline Operational Noise and its Potential to Impact Toothed and Baleen Whales

Randal Glaholt, John Marko, and Paul Kiteck

The potential impact of pipeline operational noise on toothed whales and baleen whales was examined using a combination of field measurements, laboratory investigation and pipeline component analysis coupled with available literature on the acoustic sensitivities of toothed and baleen whales. Measurements made over a 25.4 cm (10″) outside diameter (O.D.) high pressure gas pipeline suggest that the pipeline was not producing any clearly resolvable noise. Tests on concrete-coated steel plate and pipeline segments with characteristics similar to a proposed gas pipeline indicated that the total acoustic energy, which would enter a surrounding water column, is on the order of 15 decibels (dB) lower than the energy expected in the absence of the coating. Data also suggest that the steel concrete interface can influence the acoustic transmission properties of coated steel pipelines. Laboratory results indicate a roughly linear relationship between frequency and the additional acoustic insulation (in dB) offered by concrete coating. The acoustic significance of concrete coating is likely to be confined to frequencies in excess of a few thousand Hz. The results of modeled noise output for a 40.6 cm (16″) O.D. high pressure gas pipeline indicate that radiated noise at 1 m would be about 30 dB re 1 μPa for 1/3 octave bands above 16 kHz and hence well below the minimum threshold of hearing for toothed whales (e.g., 40 dB re 1 μPa above 16 kHz). For lower frequency bands the modeled noise at 30 m from the pipeline was estimated to be below 90 dB at 31.5 Hz (1/3 octave band), suggesting that baleen whales, with hearing thresholds at 60 dB to 80 dB re 1 μPa for lower frequencies (e.g., $<$ 300 Hz) would probably not be affected by the low-frequency pipeline noise given natural ambient conditions. An upstream compressor is the primary noise generating source in gas pipelines rather than gas flow generated noise. Important factors are: the whale species involved; compressor type; presence of other pipeline components (e.g., valves, aftercoolers); pipe wall thickness, coating and exposure; water depth, chemistry and substrate. Given the low intensity of gas pipeline noise and the fact that whales typically occupy ranges over many thousands of square kilometres, significant compromise to whale communication or foraging efficiency is unlikely. To some extent pipelines may reduce the need for vessel traffic for the conveyance of hydrocarbons and as such, significantly compensate for what little noise they do make.

Keywords: Toothed whales, baleen whales, pipeline noise, pipeline design, underwater noise, marine acoustic environment

INTRODUCTION

Pipeline operational noise has been largely ignored with respect to its potential significance to marine mammals such as toothed whales (Odontocetes) and baleen whales (Mystecetes). A recent proposal to construct a high pressure gas pipeline across Georgia Strait by Georgia Strait Crossing Pipeline Limited (GSX) drew particular attention in this regard, in part driven by concern over the fact that the pipeline would traverse a portion of the seasonal range of an endangered population of killer whale (*Orca orcinus*) and uncertainty as to the extent to which pipelines could add to the ambient noise environment and hence mask

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acoustic information important to whales. To better assess the potential for a high-pressure gas pipeline to generate underwater noise with potential consequence to marine mammals, the following three research projects were undertaken:

1. Measuring noise over an existing high-pressure gas pipeline;
2. Laboratory tests to measure sound attenuation in pipe and steel plate with various coatings; and
3. Modeling the potential noise that could be generated by a gas pipeline with the same specifications associated with the GSX pipeline.

Hearing in toothed whales and baleen whales

Anatomically, the hearing structures of marine mammals follow much of the basic land mammal pattern, but have evolved further adaptations allowing them to efficiently hear underwater despite increased pressures and shortened interaural arrival times. Toothed whales, like bats, are echo-locators, capable of producing, perceiving and analyzing *ultrasonic* frequencies well above any human hearing. The majority of toothed whales have peak sensitivities (i.e., best hearing) in the ultrasonic ranges, although most have moderate sensitivities to sounds from 1 kHz to 20 kHz and have relatively sharp decreases in sensitivity below 2 kHz (Richardson et al., 1995). Presumably the hearing threshold of these species mirrors the minimum ambient acoustic environment under which they evolved. These ultrasonic dominant species (200 Hz to 100 kHz) have a minimal threshold of hearing commonly near 40 dB re 1 μPa (peak 1/3 octave band spectra) from 16 kHz to 100 kHz, and no toothed whale species have been shown to have acute hearing (< 80 dB re 1 μPa) for 1/3 octave bands below 500 Hz (Ketten, 2001). Under quiet conditions (Sea State 1), ambient noise levels for these ultrasonic frequencies are in the range of 50–60 dB re 1 μPa for 1/3 octave bands above 16 kHz. Although it is not possible to provide an absolute single number or dB level that is safe for all whale species for all signals, in general, if the species cannot hear the sound or only hear it poorly, it is unlikely to have a direct physiological effect, though this does not preclude social or energetic (e.g., food locating) implications.

Baleen whales have hearing adaptations, which allow them to localize *infrasonic* sound at frequencies below a few hundreds or tens of Hz (e.g., 15 Hz to 300 Hz), and the minimum threshold, although unknown, is speculated to be from 60 dB to 80 dB re 1 μPa (Ketten, 2001). Blue and fin whales can communicate below 20 Hz and may generate strong infrasounds at 5 Hz. In regard to ambient infrasonic noise, Richardson et al. (1995, pp. 238–239) states that "even in quiet conditions (e.g., Sea State 1) without any industrial activity nearby, the average ambient noise levels in the ocean are above 75 dB re 1 μPa in 1/3 octave bands below 1 kHz." For baleen whales, ambient ocean noise rather than absolute threshold detection usually would limit detection by baleen whales and other infrasonic species.

METHODS

Acoustic measurements over an existing gas pipeline

Measurements were made over a high pressure gas pipeline off the coast of British Columbia, Canada in 2001. Measuring equipment consisted of a calibrated hydrophone, broadband acoustic sampler and datalogger. The acoustic sampler was designed to sample full bandwidth frequency in the range of 5.4 Hz to 22,050 Hz at a 44,100 Hz sampling rate. Full 22.5 dB gain was used for all recordings. Approximately 3 to 5 minutes of data were recorded at each location/depth. Pipeline noise measurements were taken about 280 m offshore in 25 m to 26 m water depth. Measurements were taken approximately 10 m west/offshore of the point at which the two, 25.4 cm O.D. steel pipes emerged from a gravel cap. The two pipes were about 1 m to 1.5 m apart, and about 1 m off the bottom. Measurements were taken at 1 m, 5 m, 10 m and 15 m above the pipelines. "Ambient" measurements were taken approximately 1 km away.

Measurements of sound transmission through concrete pipeline coating

Measurements of the extent to which high frequency acoustic waves in gas pipeline interiors are attenuated on their passage into the water column by exterior concrete coating were carried out in water-filled tanks using short (1 cycle) pulses of 15 kHz acoustic waves generated and detected by purpose-built (by Airmar Inc.) broadbeam (60 degree, 3 dB beamwidth) transducers with 15 kHz center-frequencies. Measurements were carried out on both 50.8 cm (20″) lengths of 40.6 cm O.D. steel pipe and on 60.9 cm × 50.8 cm sections of 1.42 cm thickness steel plate. The pipe sections, with 0.635 cm wall thicknesses, were tested both bare and with a 7.302 cm concrete coating similar to but thicker than the 4.127 cm coating to be applied to the GSX pipeline. The flat plates were employed to obtain measurements on steel with thicknesses close to that of the deployed pipes and to allow us to quantify expected dependences of pipeline sound insulation properties on concrete coating thickness. The latter dependences enabled the application of results to a proposed pipeline design which had a 1.5875 cm steel wall thicknesses and a 4.127 cm concrete coating. Applications of coating to these plates followed, as closely as possible, the procedures used by the proposed pipeline manufacturer. Concrete curing, under mechanically-applied (weights) pressure, was carried out for several days prior to use of the plates in the testing program.

Measurement methodology used uncalibrated transducers, relying solely upon comparisons of integrated acoustic signal intensities arising from common voltage pulse inputs to the transmitting transducer. The integrated intensities associated with signals as detected at fixed distances from transmitting transducer after transmission through the water column with and without passages through different combinations of bonded steel and concrete layers, provided the basis for estimating the effects of concrete coating on levels of high frequency sound emanating from pipeline interiors. After initial testing along nominally horizontal acoustic paths in the larger, 0.95 m × 0.67 m × 1.5 m. laboratory tank, all quantitative measurements were eventually carried out in the smaller (1.15 m × 1.15 m × 1 m) test tank, using vertically-propagating acoustic waves and a common 78 cm spatial distance between the transmitting and receiving transducer faces. Side view representations of the measurement configurations are given in Fig. 1a and Fig. 1b, respectively for the flat plate and pipe section tests. In initial tests, carried out in preparation for the formal NEB hearings, this initial coating consisted of a layer of paint, which was judged to be a suitable (in acoustic properties) surrogate for the fusion-bonded epoxy (FBE) coating which would actually be applied to the outer metallic surfaces of the steel pipe used in the deployed pipeline. Subsequent testing on identical FBE-coated surface was used to quantify the extent to which this short-cut could have affected the obtained results.

Use of very short (1 cycle) pulses and a relatively large, 78 cm measurement range allowed comparisons of transmitted acoustic signals without complications arising from overlap with similar, time-varying signals detected by electromagnetic induction. The latter signals were coincident with the large 15 kHz voltage pulse used to drive the transmitting transducer as originally generated by a Wavetek Model 191 20 MHz Pulse/Function Generator and amplified by a Pioneer SA-301 Stereo Amplifier. The received acoustic signals were detected by the receiving transducer after suitable propagation, speed, and path-determined delays, which were on the order of 500 to 600 microseconds. The minimum (non-negligible) delays were associated with the first arrivals of acoustic signals which propagated, usually with a small number of reverberations or internal (to the steel and concrete plates/walls) reflections, directly from the transmitting- to the receiving-transducers. Subsequent signal arrivals, typically following on for as much as one millisecond after the first direct arrivals, were also detected, which corresponded to signals undergoing at least one reflection from the walls and floor of the tank or from the surfaces of the plates, pipes and transducers. Such reflected signals would not be a prominent feature of the pipeline noise field in the ocean environment; however, our analyses were focused on the direct arrival acoustic signals and, in particular, on the dependence of their time integrated intensities on the thickness of concrete layers added to the tested steel surfaces.

After completion of the measurements and initial analyses, additional measurements were carried out in an attempt to estimate the dependence of the observed loss factors on the frequency of the sound waves transmitted through the bare and concrete-coated steel plates considered in our studies. Such data are relevant to estimates of possible above-background noise generation by the GSX pipeline across a wider portion of the acoustic spectrum, and specifically at frequencies significantly lower than the 15 kHz value considered in the principal part of our measurement program. Ideally, acquisition of such data requires use of a succession of transducers each tuned to efficiently transmit and receive signals in bands with progressively lower centre-frequencies. On the other hand, given the relatively modest estimates obtained for the concrete-related loss factors, it was judged sufficient to obtain estimates of the rate at which such losses change as a function of frequency within the bandwidth of the transducers used in the 15 kHz studies. Measurements were, thus, carried over frequencies between 4 kHz and 20 kHz but, because of the sharp falloff in transmitting and receiving response as one moves away from the 15 kHz center frequency, meaningful data were obtained only for frequencies between 8 kHz and 20 kHz.

All-frequency-related measurements were carried out on plates, which had been previously given a commercial FBE coating similar to that incorporated on the concrete-coated pipe section. Consequently, the tested steel plates differed from all previously tested plates and pipe sections in that their surfaces were fully encased within FBE layers. No equivalent protective layer was present on either the inner (i.e., in contact with the face of the sound-generating transducer surface) surfaces of the two tested pipe sections or on the surfaces of the previously tested bare and concrete-coated plates.

Modeling of GSX noise potential

Pipeline characteristics

The hypothetical section of pipe considered for the purpose of modeling sound was based on the design parameters of the GSX pipeline. It was presumed that the pipeline would first be exposed to the marine environment 10.6 km from the nearest compressor, and remain exposed to the marine environment for a total of 67 km before its next landfall. The offshore section of the pipeline was taken to consist of a 40.6 cm diameter steel pipe 1.435 cm wall thickness) with a 4.127 cm concrete coating although the initial 0.3 km will not include the concrete coating but will have a wall thickness of 2.2 cm. The underwater section of the piping had the following general design conditions and dimensions/parameters:

- Typical gas flow rate: 100 MMscfd (steady-state).
- Range of outlet (delivery) pressure: 700 psia (minimum) to 2,200 psia (maximum discharge).

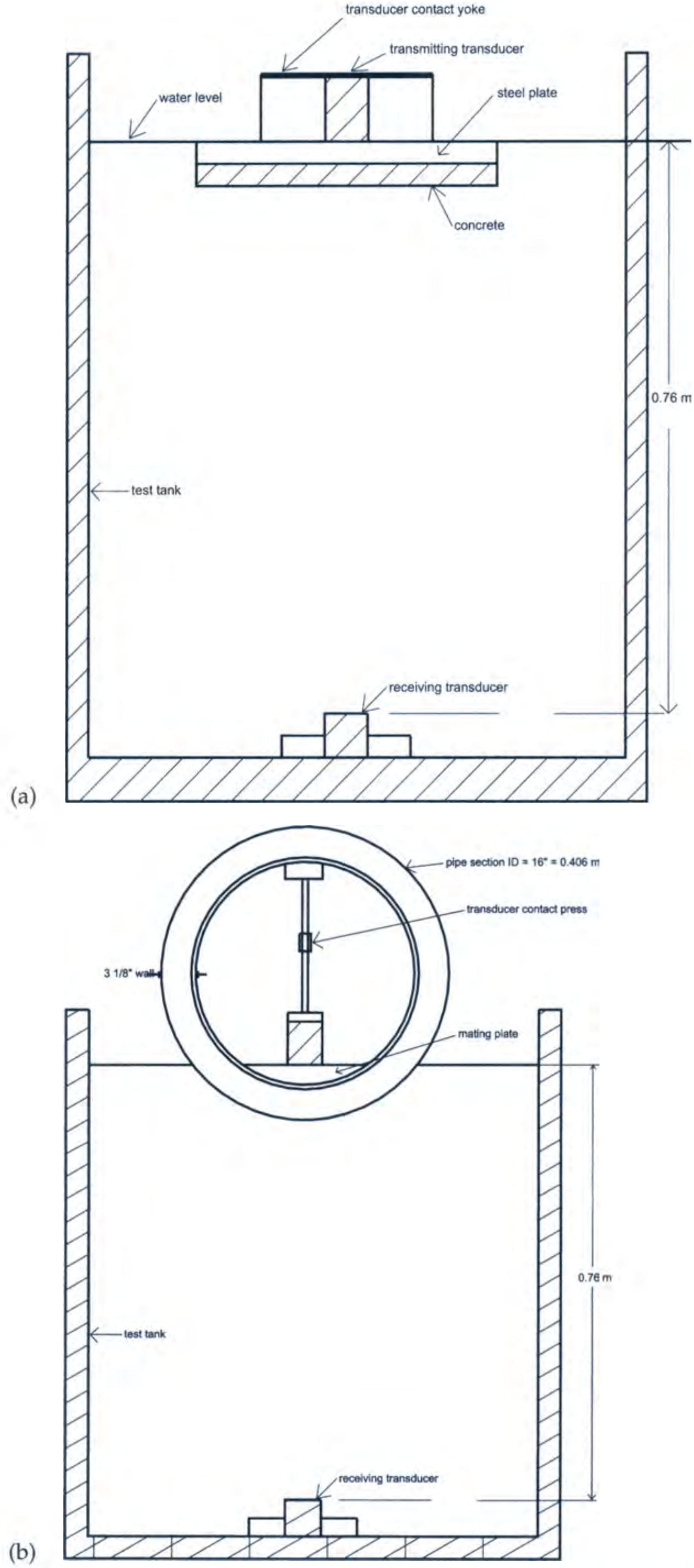


Fig. 1. Schematic representations of the sound insulation measurement configuration for (a) flat plate specimens and (b) pipe section specimens.

Table 1. Assumption parameters for gas flow noise evaluation

GSX Pipeline Geometry		
Pipeline Inside Diameter	14.688	inches
Pipeline Wall Thickness	1.10	inches
(represents the equivalent w.t. of an all steel pipeline)		
GSX Pipeline Low Velocity Condition (at Cherry Point Landfall)		
Pipeline Pressure	2170	psia
Pipeline Temperature	75	deg. F
Gas Flow Density	8.21	lbs./cu. ft.
Gas Flow Velocity	5.5	ft./sec.
Gas Flow Velocity	3.8	miles/hr.
Gas Flow Velocity	6.0	km/hr.
GSX Pipeline High Velocity Condition (at Manley Creek Landfall)		
Pipeline Pressure	775	psia
Pipeline Temperature	51	deg. F
Gas Flow Density	2.84	lbs./cu. ft.
Gas Flow Velocity	15.9	ft./sec.
Gas Flow Velocity	10.8	miles/hr.
Gas Flow Velocity	17.4	km/hr.

- Dimensions parameters: Initial 0.3 km (1,000 ft): O.D. = 41 cm, Inside Diameter (I.D.) = 38.80 cm, wall thickness = 2.2 cm, corrosion coating (FBE) thickness = 0.0406 cm, and interior roughness of pipe = 0.00457 cm. Remaining Offshore Segment: O.D. = 41 cm, I.D. = 37.307 cm, wall thickness = 1.666 cm, corrosion coating (FBE) thickness = 0.0406 cm, and interior roughness of pipe = 0.00457 cm.
- Concrete weight coating: 140 pcf and thickness of 4.1275 cm.

Description of the compressor station

The GSX compressor station design specification called for one (1) Solar Taurus 70 turbine (ISO rating of 10,300 HP) driving a Dresser Rand (DR) Model D8R9B "Datum" centrifugal gas compressor. The compressor station was designed to boost the pressure of natural gas from a pressure of approximately 500 psia to a maximum pressure of approximately 2,200 psia. The following describes equipment and other notable items associated with the compressor station:

- DR centrifugal compressor is a single body (i.e., multi-stage) unit designed with an internal wheel that includes nine (9) impellers that are driven by the turbine at 11,000 rpm;
- Turbine and compressor located inside a building (i.e., compressor building);
- Outdoor lube oil cooler for the turbine/compressor;
- Outdoor gas aftercooler (i.e., employed to lower the discharge gas temperature);
- Turbine exhaust muffler/stack system and turbine air intake filter system; and
- Aboveground gas piping in the station yard and associated unit valve skid.

Description and calculation methodology for "flow-generated noise"

The GSX pipeline flow noise was estimated utilizing the Gas Flow Noise Evaluation.xls Workbook that was developed under contract to NASA (NASA, 1999). The Gas Flow Noise Evaluation Workbook predicts the noise emission due to the interaction of the turbulent boundary layer in the gas with the walls of the pipe. The Gas Flow Noise Workbook performs computations of sound power level (PWL or Lw Re if only using a picowatt or 10–12 watt) and sound pressure level (SPL or Lp re 20 μPa) at 1 m from a 304.8 cm length of pipe (in air). For our analysis, we have evaluated the low and high pipeline velocity conditions, as these two cases represent the lower and upper levels of "flow generated noise," respectively. Table 1 lists the assumptions that were utilized with the Gas Flow Noise Estimation Workbook.

The low velocity condition occurs when the pipeline is operating at the highest flowing pressures (i.e., when the gas is most compressed). As shown in Table 1, the lowest velocity of 1.67 m/s or 6.0 km/hr occurs at the Cherry Point Landfall with a 2,170 psia flowing pressure and 23.9 degrees C flowing temperature. The high velocity condition occurs when the pipeline is operating at the lowest flowing pressures (i.e., gas is least compressed), and the highest velocity of 4.84 m/s or 17.4 km/hr occurs at the Manley Creek Landfall with a 775 psia flowing pressure and 10.5 degrees C flowing temperature.

Analysis methodology for calculating noise in the piping due to an upstream compressor

In general, the predicted noise radiated from the gas pipeline resulting from a mechanism that contributes to internal pipeline noise (i.e., gas compressor) was calculated as a function of frequency from estimated unweighted octave-band SPLs. The estimated piping noise radiated into the ocean is presented in level per specific frequencies (as related to the octave band center frequency). The following summarizes the analysis procedure:

1. Initially, unweighted octave-band SPLs (i.e., dB re 20 μPa) at 1 m outside the discharge piping for the gas compressor were determined from sound data obtained from the equipment manufacturer (provided by Dr. Zheji Liu, Acoustic Specialist for Dresser Rand);
2. Then, the octave-band SPLs inside the discharge piping due to the compressor were estimated by adding the estimated sound transmission loss (TL) of the piping to the outside SPLs;
3. Then, expected noise reduction in dB per octave-band frequency due to gas aftercooler and other pipeline-related components that could provide attenuation of the compressor noise (e.g., turns/bends in the pipeline, valve skid and downstream valves) were subtracted from the estimated SPLs to obtain the estimate SPLs inside the pipe prior to propagating down the pipeline from the station yard. The anticipated noise reduction due to the gas aftercooler and pipe-related components is based primarily on sound tests in the field by Hoover & Keith;
4. Next, the octave-band SPLs inside the piping at the point that the pipeline lays on the ocean bottom were determined by compensating for sound attenuation due to the effects of molecular vibrational relaxation and classical absorption mechanisms of natural gas at high pressures; and
5. Then, after converting the octave-band SPLs to the appropriate 1/3-octave band level, the sound pressure level (i.e., dB re 1 μPa) radiated at a distance of 1 m from the underwater pipeline was estimated by compensating for the TL of the "thick" piping (i.e., steel pipe plus concrete coating) and conversion of the level from air to water.

RESULTS

Secret cove measurements

Spectral analyses were performed on the various time series of noise recordings. The time series were analyzed in blocks of 2,048 points each, representing 0.0464 seconds per block (1,290 blocks per minute). Block averaging was then used to improve the statistical reliability. The two background, or ambient noise spectra are actually more energetic than those recorded above the gas pipelines. Noise spectrum levels ranged from about 68 dB to 88 dB in the 100 Hz to 1,000 Hz frequency range. These relatively high noise levels were due to the presence of vessel (primarily tugboat) generated noise and the peak at about 1,300 Hz is characteristic of outboard motor noise. The noise spectra obtained at varying distance above the gas pipelines indicates resolvable sound in the 80 Hz to 480 Hz band (Fig. 2). The sound has an "organ pipe" structure (Dr. Trevorrow, pers. comm.) with a fundamental tone at 80 Hz, and harmonics up to 480 Hz. The spectra have a peak in the second harmonic with spectral intensities near 72 dB (re 1 $\mu Pa^2/Hz$). These are about 10 dB lower than the ambient values, representing about ten times less power or intensity ratio. Above 500 Hz, the noise is similar to the classic Knudsen curve for Sea State 1. Importantly, the lack of clear and consistent reduction in sound energy levels with increasing distance from the pipe for all frequencies plus the higher energy frequency matching or mirroring under "ambient" conditions at 1 km, strongly suggest, that for the measuring equipment deployed, the pipeline was not producing any detectable noise.

Initial inspection of the data suggested that a discernible pipeline noise signature in the vicinity of the 15 kHz band that might exceed Knudsen Sea State 0. After further consideration, this conclusion is not supportable by absolute spectrum level data on their own, again due to the lack of consistent signal energy reduction at distance from the pipeline, higher energy frequency mirroring at ambient sites and due to the significant uncertainties involved in linking acoustic spectrum levels to Sea States. Ross (1976) noted that the Knudsen ambient spectrum levels tend to be high relative to true deep water oceanic levels because of their acquisition from measurements in oceanic waters only about 200 m deep outside harbors. In a similar manner, the ultimate minimum spectral levels attainable in the even shallower, 25 m waters adjacent to the Centra pipeline measurement area would be expected to be elevated even further beyond the high Knudsen expectations. Urick (1983) has noted that the magnitude of this coastal elevation of minimum noise levels is on the order of 5 dB to 10 dB or large enough to account for the high frequency levels being compatible with local Sea State 0 values. In short, the absence of wind, wave, current and obvious external (i.e., boat, airplane, etc.) noise sources easily detectable by observers cannot on its own justify attributing deviations from deep ocean minimum spectral levels to pipeline noise. Such a conclusion is particularly appropriate for the relatively constricted acoustic environment adjacent to a pipeline landfall, which can effectively concentrate acoustic energy propagating from more distant, weak noise sources.

The fact that measured acoustic spectrum levels rose as measurements were made at shallower depths and, hence, at greater vertical distances from the seafloor pipeline, suggest the principal noise sources in the quiet measurement period reside in the upper water column or at the air/water interface or, possibly, even on the nearby shoreline. Indirect evidence for this interpretation was provided by subsequent measurements of background noise levels along the proposed GSX pipeline route (Birch and Glaholt, 2001). These results obtained at depths of 30 m in water 50 m to 60 m deep, indicated minimum 15 kHz spectral levels to be

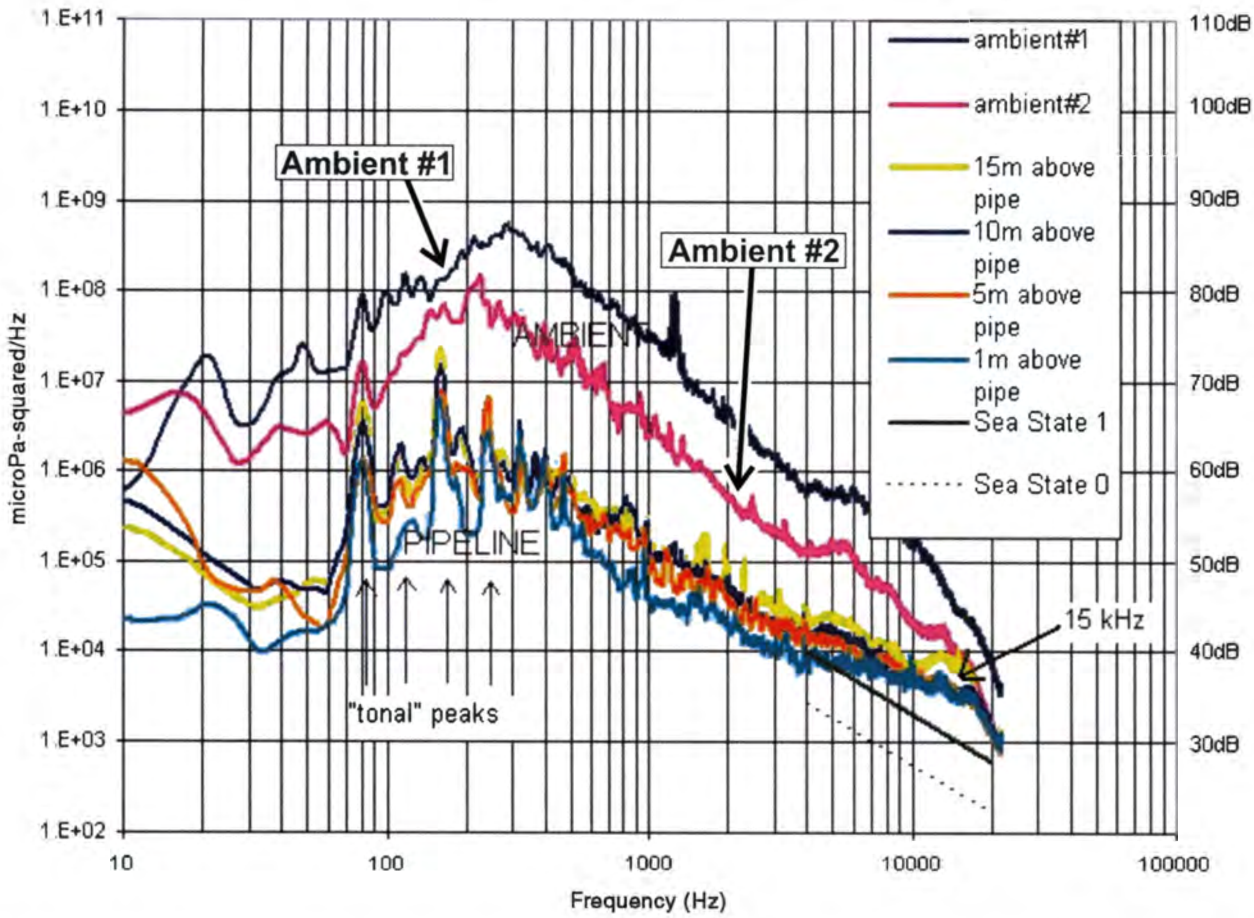


Fig. 2. Spectrum levels as measured at Secret Cove and accompanying representations of the high frequency portions of oceanic noise expectations for Sea States 0 and 1. Arrows denote the high (15 kHz) and low frequency "tonal" noise component discussed in the text.

roughly 5 dB lower than the minimum levels attained near the seafloor in the 25 m deep waters at the measurement site. This result is consistent with a tendency, in the absence of obvious boat or airborne noise generation, for minimum attainable acoustic spectrum levels to decrease with the depths of both the noise measurements and the overall water column.

For measurements directly above the pipeline, spectrum levels would be expected to decay monotonically as the inverse of the separation from the pipe. In other words, the pipeline noise levels 15 m above the pipeline should have been reduced by a factor of fifteen or about 11.75 dB relative to those observed 1 m above the pipe (as opposed to the observed 3 dB increase). Possibilities for deviations from a monotonic decay could potentially occur when the acoustic wavelengths are comparable to or larger than the water depths. Evidence for the presence of such modal structures, which arise from interference effects, may be present in the non-monotonic depth- and frequency-dependences associated with the 80 Hz fundamental and harmonic "tonals" which, as noted above, dominate the observed low frequency spectrum (Fig. 3). At the 10 cm wavelengths associated with 15 kHz acoustic waves such modal structures would not have been detected by the equipment deployed. In fact, although the waveguide modes are suggested as one possible source of the anomalous strength of the low frequency tonals at 1 km ranges, there is no possible way such modes could account for the observed intensity discrepancies. Specifically, even if no additional signal attenuation occurred after the cylindrical propagation period (a very generous assumption since several reflections off the air and seafloor interfaces would be required) the tonal intensities at 1 km distance should be about 14 dB below those measured 1 m above the pipeline in waters 25 m deep. Nevertheless, the observed 1 km levels were about 14 dB higher that the 1 m values, implying that noise generation by the pipeline decreased almost one thousand-fold in the interval between measurements made, alternatively, 1 km and 1 m from the pipeline. This result, combined with the inability of a diver (R. Glaholt, pers. comm.) to hear a low frequency "hum" with his ear physically in contact with the pipeline, suggests very strongly that the observed low frequency tonal peaks did not originate in the pipeline. In summary: the time and spatial variations associated with all available spectral data are fully consistent with the conclusion that both the narrow- and broad-band components of the spectral

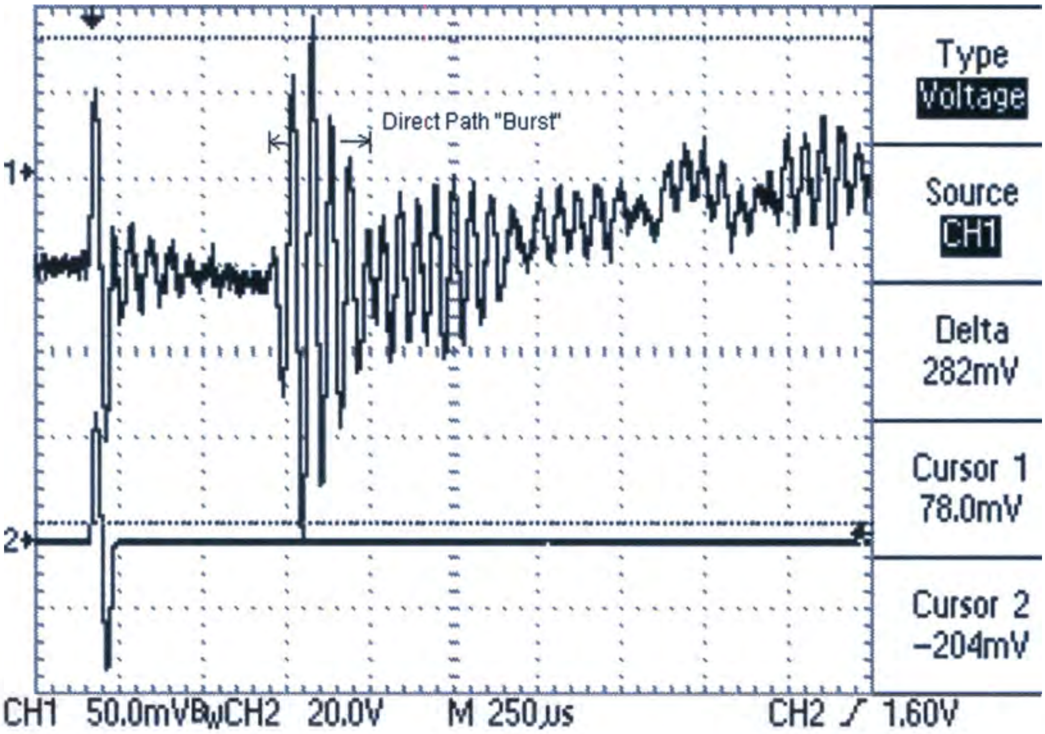


Fig. 3. Voltage output of the amplified pulse/function generator (lower trace) and the receiving transducer (upper trace) as a function of time for 15-kHz transmissions through a bare 1.42 cm thick steel plate.

measurements show no evidence of detectable contributions from the pipeline at Secret Cove. The physical evidence, in terms of the dependences of the noise levels on range and position in the water column relative to the purported source, strongly supports the proposition that the high frequency noise generated by the pipeline did not exceed local ambient noise levels in a period associated with nominally undetectable wind-, wave-, and current-generation.

Measurements of sound transmission through concrete pipeline coating

Significant distinctions can be made between the utility of, alternatively, the flat plate- and pipe-section measurements made in our study. In the first case, general information on the effects of different levels of concrete thickness and, possibly, different qualities of concrete/steel bonding were obtained from the accumulated transmission data. The measurements on the two available sections of bare and concrete-coated pipes, on the other hand, enabled direct comparisons of the general flat plate information with the acoustic measurements made on objects very similar to those which would be deployed in the proposed pipeline.

Flat plate results

Results obtained from applications of a single cycle acoustic signal centred at 15 kHz are displayed in Fig. 3 as recorded on a Tektronix TD210 60 MHz digital oscilloscope. The lower signal displays the single cycle output of the amplified Pulse/Function Generator, which triggers the start of both sweeps of the dual beam oscilloscope. The upper trace represents the signals detected by the receiving transducer near the bottom of the test tank (see Fig. 1a and Fig. 1b). As indicated at the bottom of the display, the large (dotted) divisions along the (horizontal) time axis are 250 microseconds and the corresponding (vertical) divisions denote 20 v and 50 mv (0.05v) divisions for the lower (input) and upper (output) voltages, respectively.

The first, rapidly-decaying signal at the left hand end of the upper trace represents the electromagnetic response of the receiver circuitry to the electromagnetic pulse, which initiates the acoustic pulse generation at the transmitting transducer (positioned with its face at the upper water surface, 76 cm above the face of the equivalent receiving transducer). The next significant component of the received signal consists of a roughly 4 cycle burst, which begins to appear, roughly, 550 microseconds after the start of the triggering pulse. This burst represents the direct arrival signal and subsequent reverberations (i.e., signals, which undergo several reflections inside the steel plate which, through interference, produces the indicated peaking of the signal amplitude). This characteristic burst, specifically labeled in the figures, is closely followed by similar but weaker signal bursts associated with longer propagation paths, which include, intervening bounces off the adjacent tank sidewalls and, at later times, bounces off the tank floor, the steel plate and the water/air interface. As indicated above, we have made no attempt to unravel these additional signal components and have focused on the direct signal component in studying

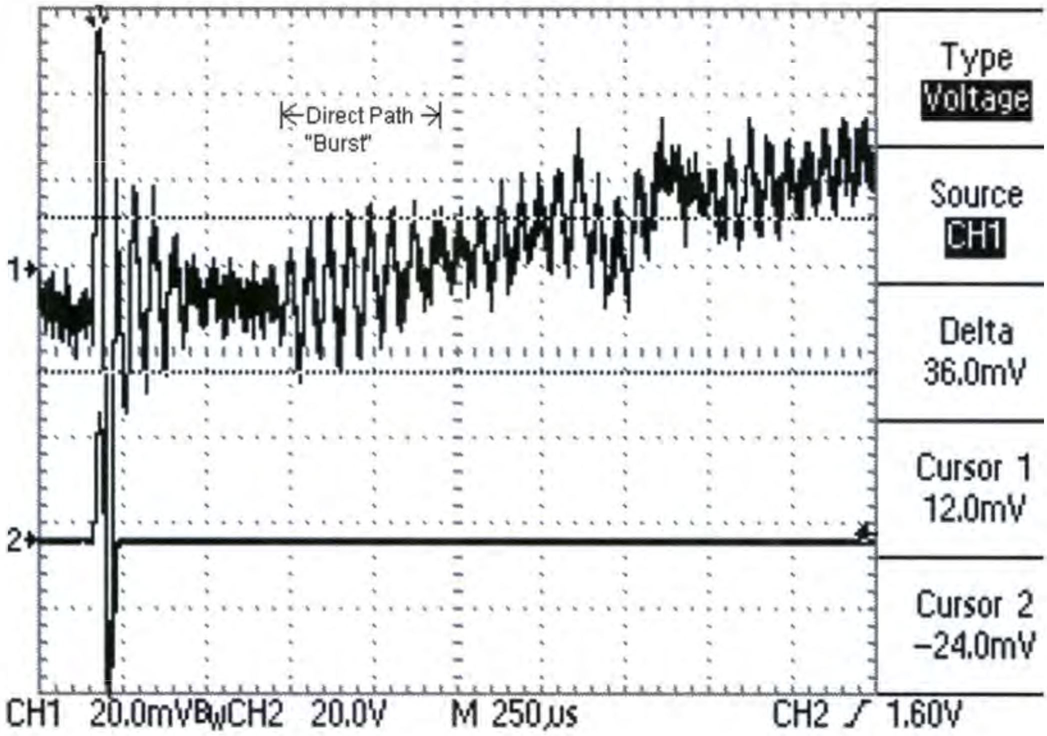


Fig. 4. Voltage output of the amplified pulse/function generator (lower trace) and the receiving transducer (upper trace) as a function of time for 15 kHz transmissions through a 1.42 cm steel plate coated on its undersurface (not in contact with the transmitting transducer) with a 4.127 cm layer of concrete.

the extent to which additions of concrete coating affect acoustic transmission through the steel medium.

Inspection of equivalent signals obtained with identical forcing of a similar steel plate and an applied (on the plate face opposite that in contact with the transmitting transducer) 4.127 cm coating yielded the similar-looking traces of Fig. 4. In this case it should be noted that the vertical scale divisions correspond to smaller (20 mv vs. 50 mv) voltages relative to the bare plate results of Fig. 3. The other notable feature of the coated plate data is the lengthening of the direct pulse portion of the signal from the four relatively distinct cycles evident in Fig. 3 to approximately 7 cycles, which precede signal fading and the start of overlap with the first arriving indirect signal, roughly 1,100 microseconds after the start of the trace.

Interpretation of these results and of comparable data gathered on the plates coated with 2.063 cm and 7.302 cm layers of concrete requires translation of the individual pulse results into the constant sound generation situation proposed to be associated with gas pipelines. In the latter case, the critical information in the changes detected at any one point is the total amount of acoustic energy leaving the pipe as one changes the thickness or other properties of the added concrete coating. Consequently, the appropriate basis for comparisons of bare and coated pipeline results must take into account both the changes in the amplitude of the transmitted direct propagation signals and the usually lengthened duration of the signal reverberations as indicated in the comparisons of the direct path burst portions of the signals in Figs. 3 and 4. Given the relatively low levels of the detected signals, this basic comparison of acoustic energy transmission or "leakage" in terms of time-integrated acoustic intensity can be adequately approximated by the product of the square of the average signal amplitudes during the direct path signal "burst" with burst duration. Such integrated intensities were computed on the basis of transmission data gathered for all four tested flat plate cases (bare plate and bare plate +2.063 cm, 4.127 cm and 7.302 cm concrete coatings) and presented in Table 2 in terms of dB units referenced to the intensity obtained with the bare steel plate. Table 2 also includes conversion of ratios of these measures of integrated signal strength for the coated plate into dB relative to the integrated signal strength emanating from the bare steel plate.

Table 2. Time-integrated acoustic intensities transmitted through steel plates coated with the indicated thicknesses of concrete as expressed relative to bare plate integrated intensities

Plate composition	Integrated intensity relative to bare plate (dB) value
Bare	–
Bare + 0.6125″ concrete coating	− 17.3
Bare + 1.625″ concrete coating	− 13.5
Bare + 2.875″ concrete coating	− 11.3

These results suggest that the total acoustic energy, which would enter a surrounding water column through a concrete-coated steel plate, is on the order of

15 dB lower than the energy expected in the absence of the coating. It is not clear whether the apparently counter-intuitive tendency for leakage to increase with increasing coating thickness represents a true effect of thickness on energy transmission. It cannot be discounted that differences in the concrete-steel bonding layer may have arisen from the sensitivity of the bonding conditions to concrete thickness introduced by our efforts to manually duplicate the coating application procedures employed in commercial pipeline production. This suspicion and the possibility that the nature of the steel concrete interface may control the acoustic transmission properties of coated steel is consistent with the results of theoretical calculations of acoustic transmission through "perfect" transitions between steel and water, as well as from steel to concrete to water. Obtained using the standard formula (Kinsler et al., 1982) for wave intensity transmission (and ignoring both interference and (small) wave attenuation effects) these calculations suggested that the net transmission coefficients from steel into water would be 0.12 and 0.26 in the absence and presence, respectively, of an intervening concrete layer. The failure to observed such an, approximately, 6 dB increase (an impedance-matching effect) in sound transmission introduced by the concrete coating suggests the possible importance of the intermediate paint and or epoxy layers, although some sensitivity to concrete thickness could also be expected from the interference effects reflected by the "ringing" characteristic of the observed burst signals.

These differences in the preparation of the tested steel surfaces appeared to have notable impacts on the character of the transmitted acoustic signals. This effect was seen in the traces of the signals obtained after transmission of 15 kHz pulses through, first, the concrete-free FBE-encased plate and subsequently, through an identical plate with a 4.12 cm concrete coating applied to its outer (i.e., opposite the surface in contact with the transducer) surface. The signal obtained with the concrete-free plate was readily distinguishable from its FBE-free counterpart. In the former case, the separate arrivals of successive 4 to 5 cycle signal bursts are apparent, whereas the signal transmitted through the FBE-coated plate showed a very fast rise to a peak amplitude followed by a fairly monotonic decline over a subsequent 600 microsecond interval, before leveling off and holding a still lower signal level. Overall, the peak amplitude of the received signal was about 60% of that evident in the FBE-free plate (Fig. 3). This result suggests that the details of thin boundary layers separating the steel from adjacent concrete, water and transducer face-media, do impact directly upon the strength of signal transmitted into the water column. In this case, replacement of a paint underlayer by an FBE equivalent and the addition of a similar layer on the inner, transducer-driven, plate surface, significantly (by about 4 dB) reduced the strength of the first burst signal as well as the strength and time-dependence of the subsequent later signal arrivals.

Table 3. Comparisons of "first burst" intensity through an FBE-coated plate with 4.12 cm concrete coating expressed in dB relative to intensities obtained in the absence of the coating

Frequency (kHz)	Integrated intensity relative to bare FBE-coated plate value (dB)
8.0	−9.8
15.0	−16.8
20.0	−17.5

Additional notable changes were also apparent in the character of the transmitted signal associated with transmissions through the concrete-cladded, FBE-coated plate. In particular, the signals obtained after transmission through the FBE-coated plate and it's bonded outer 4.12 cm thick layer of concrete showed unique character in that the strongest portions of the received signal arrived, roughly, 500 microseconds after the first arrival of the "first burst" signal. This latter arrival time should have been slightly in advance of the first signal arrivals. While measurable "first burst" signal intensities were observed, signals of almost double their observed amplitudes were observed immediately following signal bursts.

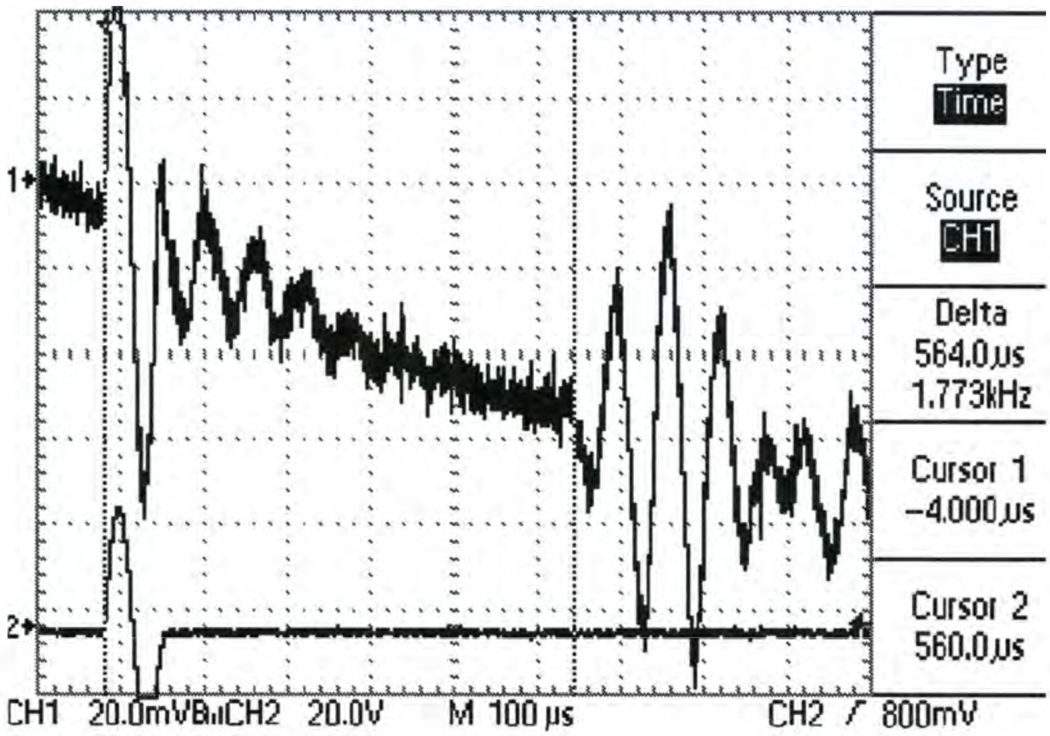
Tests showed that such anomalous stronger second burst signals were present at all frequencies in the 8 kHz to 20 kHz frequency range associated with detectable transmissions through the concrete-cladded, FBE-coated plate. While suggestive of additional complexities introduced by the presence of the FBE-layer, such results are not of immediate interest in establishing the frequency dependence of the acoustic insulation effectiveness of concrete coating. Consequently, our measurements were confined, as in the foregoing sections of this report, to comparisons of the integrated intensities of the "first burst" signals, since such comparisons facilitate extrapolation of our 15 kHz results to other portions of the frequency domain.

Results obtained from these comparisons are presented in Table 3 for three frequencies in the tested range. These results are compatible with a roughly linear relationship between frequency and the additional acoustic insulation (in dB) offered by concrete coating. They suggest that the acoustic significance of concrete coating is likely to be confined to frequencies in excess of a few thousand Hz.

The importance of these issues, concerning the nature of the concrete steel interfaces, are examined indirectly in the following section, which presents results from similar acoustic measurements on coated and uncoated pipe sections similar, but not identical, to those which would be incorporated in the GSX pipeline.

Pipe section results

Measurements on the bare and 7.302 cm concrete-coated pipe sections differed from those made on flat



Note: In this case, the signal is displayed on a time scale of 100 microseconds per division and at a vertical scaling of 20 mv per division for the received (upper) acoustic signal.

Fig. 5. Voltage output of the amplified Pulse/Function generator (lower trace) and the receiving transducer (upper trace) as a function of time for 15-kHz transmissions through the bare 40.6 cm O.D. steel pipe.

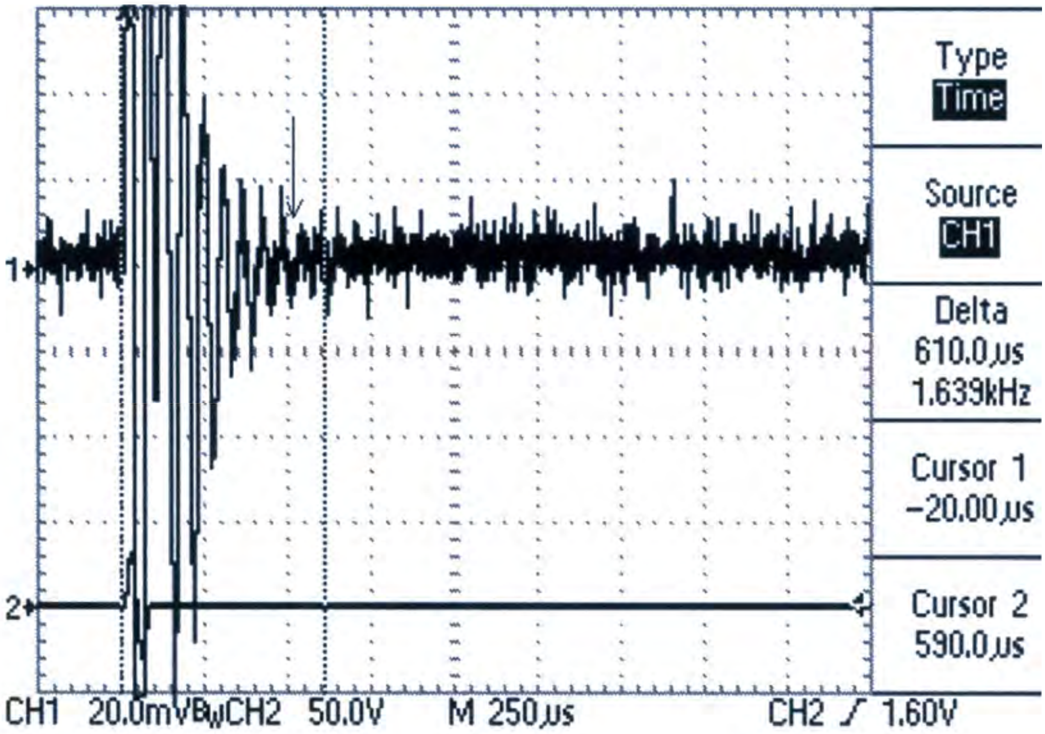
plates primarily through the necessity for the use of an additional "mating plate" in order to assure good physical contact and signal transmissions from the flat face of the transmitting transducer into the curved inner surfaces of the pipe sections. This difference produced a roughly 6 dB decrease in the signals detected by the receiving transducer in tests on the bare pipe (Fig. 5). Figure 5 highlights the structure of the upper (acoustic) direct path "burst" signal, which begins just to the right of the most rightward added vertical dotted line and prior to a brief fading and the beginning of indirect path arrivals at the extreme right-hand edge of the display. It is seen that, in this case, the "burst" signal consists of just three complete cycles, probably as a consequence of the thinner wall thickness of the pipe section as opposed to the tested plates (0.635 cm vs. 1.422 cm).

The signal received from transmissions through the coated pipe section is displayed in Fig. 6 using the larger time scale divisions previously employed in the plot seen in Fig. 3. It is seen, that, apart from the large electromagnetic induction signal at the left hand side of the acoustic signal plot, there is little unambiguous evidence of any acoustic signal transmissions along either the direct or indirect pathways so readily identifiable in the bare pipe section and flat plate signal results. Specifically, one could say that the maximum possible mean peak to peak voltage associated with the direct path burst signal (which, if present, should have begun to appear at the time indicated by the appended arrow) was unlikely to be larger than approximately 15 mv. Assuming the presence of six cycles of signal with this amplitude in the noisy signal (on the basis of the results obtained above with flat plates coated with similar thicknesses of concrete) allows calculations of time integrated intensities for comparisons with the bare pipe section. These calculations suggest that the application of a 7.3 cm concrete coating reduces the acoustic leakage from the bare pipe section by at least 14.5 dB. This finding is consistent with results obtained for steel plate and supports the assumption that the application of concrete coating to a pipeline will introduce at least a 15 dB reduction in the level of high frequency sound entering the water column.

Pipe noise generation modeling

The results are based upon detailed acoustical calculations using actual GSX pipeline characteristics, actual pipeline operating conditions, realistic flow velocities and realistic sound transmission loss values. In general there are two mechanisms that typically generate radiated sound from a long length of gas pipeline located at a significant distance downstream from a compressor station (i.e., sometimes referred to as a booster station):

1. Flow generated noise: Noise associated with gas flow inside a relatively smooth pipe that penetrates the pipe wall and radiates from the surface of the pipe; and



Note: The horizontal (time) axes employ the same 250 microsecond divisions previously used in Fig. 3. The direct path "burst signal" should have begun appearing approximately at the time indicated by the appended arrow.

Fig. 6. Voltage output of the amplified Pulse/Function generator (lower trace) and the receiving transducer (upper trace) as a function of time for 15-kHz transmissions through the steel pipe section coated with concrete 7.3 cm in thickness.

2. Compressor Station Generated Noise: Noise generated by mechanical equipment, such as an upstream gas compressor, that propagates internally down the piping and radiates from the surface of the pipe.

Any resonances or notable frequencies associated with the piping system (e.g., ring frequency, critical frequency, flexural mode resonances) are considered an acoustical or structural phenomena that are a function of and excited by these two general noise-generating mechanisms. Detailed analysis of these two potential noise sources using GSX parameters is provided in the subsections, which follow.

Flow-generated noise in the pipeline

Estimated Pipeline Flow Noise in Air

For our analysis, we have evaluated the low and high pipeline velocity conditions, as these two cases govern the lower and upper levels of "flow generated noise," respectively. The low velocity condition occurs when the pipeline is operating at the highest flowing pressures (i.e., natural gas is most compressed). The lowest velocity within the marine portion of the pipe, 1.67 m/s or 6.0 km/hr, occurs at the landfall nearest the compressor where the gas is at a 2,170 psia flowing pressure and 23.8 degrees centigrade flowing temperature. The high velocity condition occurs at the lowest flowing pressures (i.e., gas is least compressed). The highest predicted velocity, 4.85 m/s or 17.4 km/hr, occurs at the more distant marine landfall where the gas has a 775 psia flowing pressure and 10.5 degrees centigrade temperature.

The pipeline flow noise was estimated utilizing the Gas Flow Noise Evaluation Workbook developed under contract to NASA (1999), which predicts the noise emission due to the interaction of the turbulent boundary layer in the gas with the pipe walls. The Gas Flow Noise Workbook performs computations of sound power level (PWL or Lw re a picowatt or 10–12 watt) and sound pressure level (SPL re 20 μPa) at 1 m from a 3.04 m length of pipe (in air). The estimated minimum and maximum flow generated octave band SPLs and A-wt. sound level at 1 m (in air) for a 3.04 m section of pipeline are presented in Table 4 and Fig. 7.

Estimated Pipeline Flow Noise Underwater

Because the standard reference level under water (i.e., re 1 μPa) is lower than that used in air (i.e., re 20 μPa), 26 dB must be added to this reference level for air. In addition, the pressure level of sound under water is 35.5 dB greater than that of an airborne sound of equivalent intensity. Therefore, for the purpose of our analysis, the 61.5 dB correction was added to the minimum and maximum estimated SPL at 1 m (in air) from the gas pipeline. It is also necessary to apply a correction to the estimated octave band SPLs, so that

Table 4. Estimated minimum and maximum flow generated octave band SPL and A-wt. sound level at 1 m (in air) for a 3.04 m (10 ft) section of pipeline

Flow generated noise condition	SPL in dB per octave band center frequency (Hz)										
	31	63	125	250	500	1000	2000	4000	8000	16 k	A-Wt Level
Minimum Flow Generated Noise Pipeline Pressure = 2170 psia Pipeline Gas Temp. = 75 deg. F Gas Density = 8.21 lbs./cu.ft. Velocity = 3.8 miles/hr. (6.0 km/hr.)	25	13	1	−11	−24	−36	−47	−56	−72	−85	−9
Maximum Flow Generated Noise Pipeline Pressure = 775 psia Pipeline Gas Temp. = 51 deg. F Gas Density = 2.84 lbs./cu.ft. Velocity = 10.8 miles/hr. (17.4 km/hr.)	51	39	27	14	2	−10	−21	−30	−46	−60	17

Octave Band SPL Re 20 μPa rms (Note: 16 kHz octave band SPL is extrapolated from the 8000 Hz octave band data)

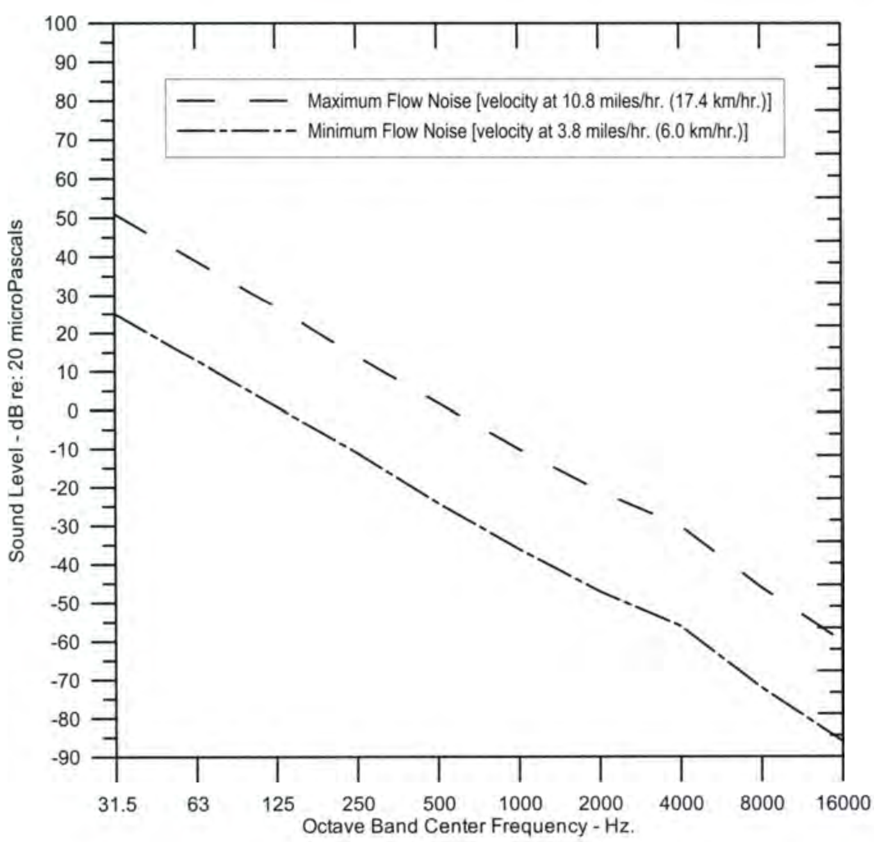


Fig. 7. Minimum and maximum estimated SPL in air at 1 m from pipeline.

the underwater levels can be estimated in terms of dB re 1 μPa per 1/3-octave band frequency. The estimated minimum and maximum flow generated noise underwater for a range of 1/3 octave bands, at a distance of 1 m from the pipeline for a 3.04 m section of underwater pipeline are presented in Table 5 and Fig. 8. The low observed signal energy appeals intuitively, given the fact that actual gas velocity inside the pipeline (e.g., 6.0 km/hr to 17.4 km/hr) and typically "smooth" inner surface of typical gas pipelines.

Mechanical equipment noise generated in the pipeline

Acoustic Attenuation inside a Pipe

Sound absorption within air (commonly called "atmospheric attenuation") has been studied extensively, especially at normal atmospheric pressure. In addition, sound is attenuated by geometrical effects such as diverging spherical propagation (where no energy is lost), whereby sound is simply spread over a larger area. In contrast, sound absorption is a transfer of acoustic energy into other non-acoustic energy forms

Table 5. Estimated minimum and maximum flow generated noise underwater at a distance of 1 m from the pipeline for a 3.04 m (10 ft) section of underwater pipeline

Flow generated noise condition	Sound pressure level in dB per 1/3-octave band frequency (Hz)									
	31	63	125	250	500	1000	2000	4000	8000	16 k
Minimum Flow Generated Noise Pipeline Pressure = 2170 psia Pipeline Gas Temp. = 75 deg. F Gas Density = 8.21 lbs./cu.ft. Velocity = 3.8 miles/hr. (6.0 km/hr.)	82	70	58	46	33	21	10	1	−16	−29
Maximum Flow Generated Noise Pipeline Pressure = 775 psia Pipeline Gas Temp. = 51 deg. F Gas Density = 2.84 lbs./cu.ft. Velocity = 10.8 miles/hr. (17.4 km/hr.)	108	96	84	71	59	47	36	27	11	−4

Sound Pressure Level in dB re 1μPa per specific 1/3-Octave Band Freq. in Hz (16 kHz level is extrapolated from 8000 Hz level data)

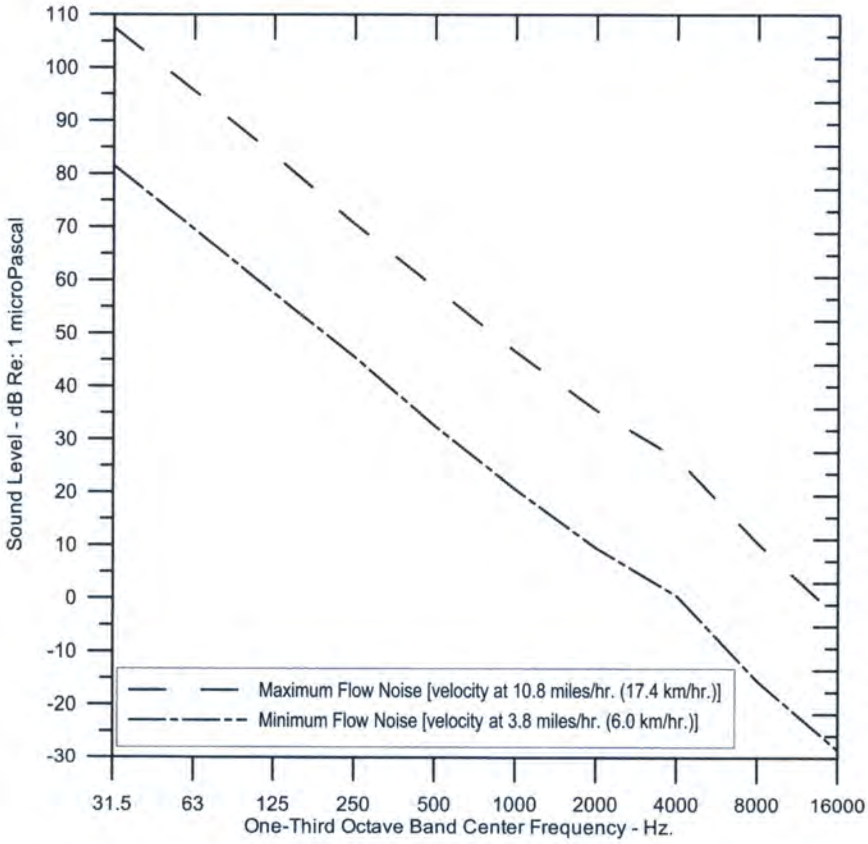


Fig. 8. Minimum and maximum estimated noise level underwater at 1 m from pipeline.

(i.e., primarily as heat). This energy absorption is due to the effects of molecular vibrational relaxation as well as the classical mechanisms of shear viscosity, diffusion of gas components and thermal conduction. In all cases, the absorption of acoustic energy reduces the sound intensity. Viscosity resists the rarefaction-compression of the gas due to the sound wave and converts some the sound energy into heat through viscous dissipation. The related heat is irreversibly conducted through the gas/medium, thereby, decreasing the sound energy. In mixtures of gas, sound waves also attenuate due to the diffusion that results from molecules with different masses moving toward equilibrium at different rates. Finally, molecular relaxation results from the phase lag in the transfer of energy from translational kinetic acoustic wave energy into internal rotational and vibrational kinetic energy during the compression-rarefaction of a gas. The phase lag leads to irreversible transformation of sound energy into heat.

Recent advances in in-pipe instrumentation using acoustic technologies have resulted in a renewed in-

Table 6. Estimated level for specific frequencies at 1 m from the underwater pipeline due to an upstream compressor

Generated noise condition	Sound pressure level in dB per 1/3-octave band frequency (Hz)									
	31	63	125	250	500	1000	2000	4000	8000	16 k
Typ. Compressor Generated Noise Pipeline Pressure = 700 to 2000 psia	92	87	84	80	74	60	60	55	40	30

Sound Pressure Level in dB re 1μPa per specific 1/3-Octave Band Freq. (Hz)

terest in the acoustic properties of multi-component mixtures of gases such as methane (i.e., primary component of natural gas). This includes not only the speed of sound, which is important for determining the wavelength but also the acoustic energy absorption (Trusler et al., 1992). Experimental data for sound dissipation in multi-component mixtures of gases appears to be sparse. However, we did find two papers that address this issue directly. The first presents a scientific explanation for the vibrational relaxation absorption of acoustic waves in gases (Dain and Lueptow, 2001a; b). Included in this paper is a comparison of the theoretical effects with experimental data for methane in addition to various mixtures of methane-nitrogen-water vapor combinations. The second paper investigates the influence of the composition of a methane-nitrogen-water vapor mixture with respect to the component concentration, frequency, temperature and pressure on acoustic gas absorption (Dain and Lueptow, 2001a; b). These results indicate that the vibrational relaxation absorption of low frequencies is dominated by the presence of even small amounts of methane, while the more classical mechanisms of shear viscosity and heat conduction is the dominant mechanism for higher frequency absorption. Our research suggests that sound inside a pipe containing high-pressure natural gas will tend to propagate much further than in normal atmosphere (in air) between 20 Hz and 20 kHz. Based on measurements at a number of facilities, our research has revealed that post compression, pipeline components (e.g., gas after-cooler, bends/turns in the pipe, valve skid and other in-pipe valves) downstream of the compressor can result in substantial attenuation of the compressor noise that propagates inside the gas pipeline.

Radiated Compressor Noise from Underwater Pipeline

The estimated noise at 1 m from the pipeline for a 3.05 m section of pipeline due to compressor noise, noting that the point where the pipeline rests on the ocean bottom (i.e., not buried/trenched) is 10.6 km downstream of the station, is presented in Table 6. The radiated noise at 1 m from a modeled 3.05 m (10 ft) section of fully exposed pipeline due to compressor-radiated noise is estimated to range from a maximum of 92 dB (re 1 μPa) at 31 Hz to 80 dB (re 1 μPa) at 250 Hz, and the radiated noise at 1 m for frequencies greater than 1 kHz is equal to or less than 60 dB (re Table 6). Low-frequency radiated sound from the pipeline (i.e., below 100 Hz) is predicted to be equal to or lower than 75 dB (re 1 μPa) at distances greater than 30 m due to propagation reduction, and as such, the radiated pipeline noise should be equal to or below the hearing threshold of baleen whales (i.e., 60 dB to 80 dB re 1 μPa for frequencies < 300 Hz).

It is assumed that the noise radiated from the underwater pipeline due to an upstream compressor would remain relatively constant and/or decrease slightly over the full length of the underwater pipeline due to low levels of acoustic attenuation in natural gas relative to air.

In general, the results of our assessment indicates that the "Compressor Station Generated Noise" will be notably higher than the "Flow-Generated Noise" for 1/3 octave band frequencies greater than 125 Hz. This is not surprising as the gas velocity inside the pipe is relatively low (i.e., anticipated gas velocities between 6.0 km/hr and 17.4 km/hr, and therefore, intuitively, one would not expect a significant amount of noise due to flow of gas inside a "smooth" pipe. In addition, the level of low-frequency noise radiated from the pipeline (i.e., frequency below 125 Hz) due to an upstream compressor should be similar to the level of low-frequency pipeline noise resulting from gas flow.

DISCUSSION

The results obtained by *in situ* measurement, laboratory testing and mathematical modeling show that the estimated sound radiated at 1 m from the underwater section of the pipeline will be equal to or lower than 30 dB for frequencies equal to or greater than 16 kHz and equal to or lower than 15 dB at 30 m [i.e., 10*log (30/1) = 15 dB], well below the minimum hearing threshold for toothed whales (e.g., 40 dB re 1 μPa above 16 kHz). Measurements further suggest that concrete coatings similar to those which would be applied to the GSX pipeline would attenuate sound leakage into the water column by an additional 15 dB. In addition, it should also be noted that the average ambient noise levels in the ocean for "quiet" conditions (e.g., Sea State 1) are 50 to 60 dB re 1 μPa for 1/3-octave band frequencies above 16 kHz. Therefore, ambient background noise would typically mask the ability of an animal to detect sound signals below 50 dB.

Regarding low-frequency pipeline noise, the estimated sound level at very low frequencies (i.e., below 100 Hz) is approximately 90 dB re 1 μPa, resulting in a low-frequency sound levels that would be equal to or lower than 75 dB at distances greater than 30 m due to propagation reduction. As a result, at moderate distances from the underwater section of the pipeline (e.g., >30 m), even baleen whales, with hearing thresholds at 60–80 dB re 1 μPa for lower frequencies (e.g., <300 Hz), would be exposed to either no or very low intensity and low-frequency pipeline noise just at their hearing threshold, especially considering that the average ambient noise levels in the ocean for "quiet" conditions (e.g., Sea State 1) are above 75 dB re 1 μPa for 1/3-octave band frequencies below 1 kHz.

The ability of any pipeline generated noise to be detected by toothed whales and baleen whales requires that the generated noise exceed ambient noise levels within the frequency range at which the species in question can hear and that the distance at which any generated noise above ambient levels overlaps with habitat normally used by whales. For this to have significance for toothed and baleen whales anthropogenic noise in the marine environment has to affect the range and efficiency of essential whale communication, and or materially influence foraging efficiency and predator avoidance. The results of this investigation suggest that pipeline-generated noise can be below ambient level or fall to background levels within the range of meters rather than kilometres. Given that whales typically occupy ranges over many thousands of square kilometres and that the signals generated from pipelines will typically tend to be at very low intensity and below or very near ambient levels, significant compromise to whale communication or foraging efficiency is therefore very unlikely to occur. Observations of marine life on and immediately adjacent to a high pressure gas pipeline in this study also indicates that gas pipelines provided habitat for a wide range of invertebrate and fish species and as such are unlikely to adversely influence habitat productivity for whales.

Results of these investigations reveal that key design and location parameters influencing potential impacts on toothed whales and baleen whales include ambient noise, compressor type (reciprocating compressors tend to generate lower frequencies than centrifugal compressors), presence of key pipeline related components (e.g., post compression after-coolers, bends, valves), pipe wall thickness, pipe coating and the potential for a given whale species to otherwise occur in an area. Other factors influencing sound transmission from marine pipelines include pipe exposure, water depth and chemistry, seabed geometry substrate type; nature of pipeline substrate contact the presence of any span correction measures (e.g., concrete mattresses, span corrections).

At present there is not a compelling basis to believe that high pressure gas pipelines represent a significant marine noise source and as such, large expenditure for routing gas pipelines around habitats frequented by whales or alternately for pipeline sound suppression measures are unjustified. There are reasonable options exist to locate compression facilities more remote from immediate coastal margins there will be some incremental reduction in marine pipeline noise that will reduce cumulative impacts to the marine acoustic landscape. Measures to reduce compressor noise on land will also result in coincident reductions in noise transmission into the marine environment. Pipelines, which are concrete coated, trenched, and or buried for other reasons or naturally settle into the substrate, will also reduce marine acoustic output. Resources are likely better spent in trying to reduce the potential noise impacts generated by vessel traffic and other high energy anthropogenic sources (e.g., seismic, high energy sonars). To some extent pipelines may reduce the need for vessel traffic for the conveyance of hydrocarbons and as such, significantly compensate for what little noise they do make.

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REFERENCES

Birch, R. and R. Glaholt. 2001. Noise generated by underwater gas pipelines: existing Centra Gas Pipeline & proposed Georgia Strait Crossing Pipeline. Unpublished report by ASL Environmental Sciences and TERA Environmental Consultants Ltd. Prepared for Georgia Strait Crossing Pipeline Ltd. 17 p.

Dain, Y. and R.M. Lueptow. 2001a. Acoustic attenuation in three-component gas mixtures – Theory. J. Acoust. Soc. Am. Vol. 109 (5), Pt. 1, 1995–1964 (May 2001).

Dain, Y and R.M. Lueptow. 2001b. Acoustic attenuation in three-gas mixture: Results. J. Acoust. Soc. Am. Vol. 109 (5), Pt. 1, 1995–1964 (May 2001).

Ketten, D.R. 2001. Marine mammal auditory systems: a summary of audiometric and automical data and its implications for underwater acoustic impacts. Woods Hole Oceanographic Institution Harvard Medical School, Oct. 11, 2001. http://swfsc.ucsd.edu/PRD/dsweb/tm-256/TM256.htm.

Kinsler, L.E., A.R. Frey, A.B. Coppens, and J.V. Sanders. 1982. Fundamentals of Acoustics, John Wiley and Sons, New York, 480 p.

NASA. 1999. Gas Flow Estimation.xls Workbook v1.2 09/07/1999. John H. Glenn Research Center at Lewis Field, Cleveland, OH.

Richardson, W.J., C.R.J. Greene, C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, 576 p.

Ross, D. 1976. Mechanics of Underwater Noise. Pergamon Press, New York, 375 p.

Trusler, J.P., M. Trusler, and M. Zarari. 1992. The speed of sound and derived thermodynamic properties of methane at temperatures between 275 K and 375 K and pressures up to 10 MPa. J. Chem. Thermodyn. Vol. 24. pp 973–991.

Urick, R.J. 1983. Principles of Underwater Sound. Peninsula Publishing, Los Altos, 423 p.

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Overview of the River and Stream Crossings Study

Scott M. Reid, Serge Metikosh, and James M. Evans

The River and Stream Crossings Study was undertaken in order to improve our understanding of the biological effects of sediment released during open-cut pipeline water crossing construction, measure the effectiveness of isolated pipeline water crossing techniques, and develop a defensible sediment effects assessment framework for open-cut pipeline water crossings. The study involved the monitoring of suspended sediment and biological effects at a series of open-cut and isolated pipeline watercourse crossings throughout Canada and the United States. The results of the studies increase the current understanding of the nature of sediment entrainment during crossing construction and the potential adverse effects on fish, benthic invertebrates and fish habitat. Predictive models were developed to estimate the potentially adverse effects. These models provided the basis of a sediment effects framework that could provide pipeline planners, construction contractors and regulatory agencies with an easy to use tool for estimating the adverse effects of pipeline watercourse crossing construction on aquatic biota.

Keywords: Sediment, water crossing, construction, aquatic effects, planning

INTRODUCTION

Construction in and around watercourses can disturb aquatic systems and cause changes to the physical, biological and (to a lesser extent) chemical components of aquatic ecosystems. Due to the large distances required to transport natural gas and oil from producing areas to processing facilities and markets, pipeline construction projects have the potential to cross numerous watercourses and adversely affect fish populations and aquatic habitats. Pathways through which pipeline crossings can affect fish and fish habitat are illustrated in Fig. 1. Excluding direct effects on fish habitat due to the disturbance of the stream bed and banks (Brown et al., 2002), the main source of adverse effects is sediment suspended into the water column during instream construction (Reid and Anderson, 1999). Potential effects of increased sediment load on downstream aquatic biota include: (1) physiological stress due to sediment exposure; (2) avoidance of habitats affected by the sediment plume; (3) reduced survival of incubating fish embryos due to the infilling of the streambed; (4) increased embeddedness of riffle habitats and infilling of pools; and, (5) changes to the abundance and composition of benthic invertebrate and fish communities.

In response to potential sediment effects, regulatory agencies in both the United States and Canada have imposed restrictions on the release of sediment during pipeline construction. This has been accomplished through numerical limits on turbidity or total suspended sediment concentration restrictions, regulatory requirements for specific crossing methods (trenchless or isolation methods) or some combination of the two. Numerical restrictions on allowable downstream suspended sediment or turbidity levels have been criticized for (Reid and Anderson, 1998a): (1) not being practically achievable; (2) failing to consider exposure duration or sediment deposition effects; (3) not incorporating expected levels of sediment generation, or sediment transport principles when defining allowable mixing zones; (4) applying numerical values defined for the protection of primary productivity in lakes (not riverine environments); and (5) failing to consider expected effects from pipeline water crossing construction. Additionally, members of the pipeline construction industry (TERA, 1996; Wolverton and Gray, 1997) have questioned the net environ-

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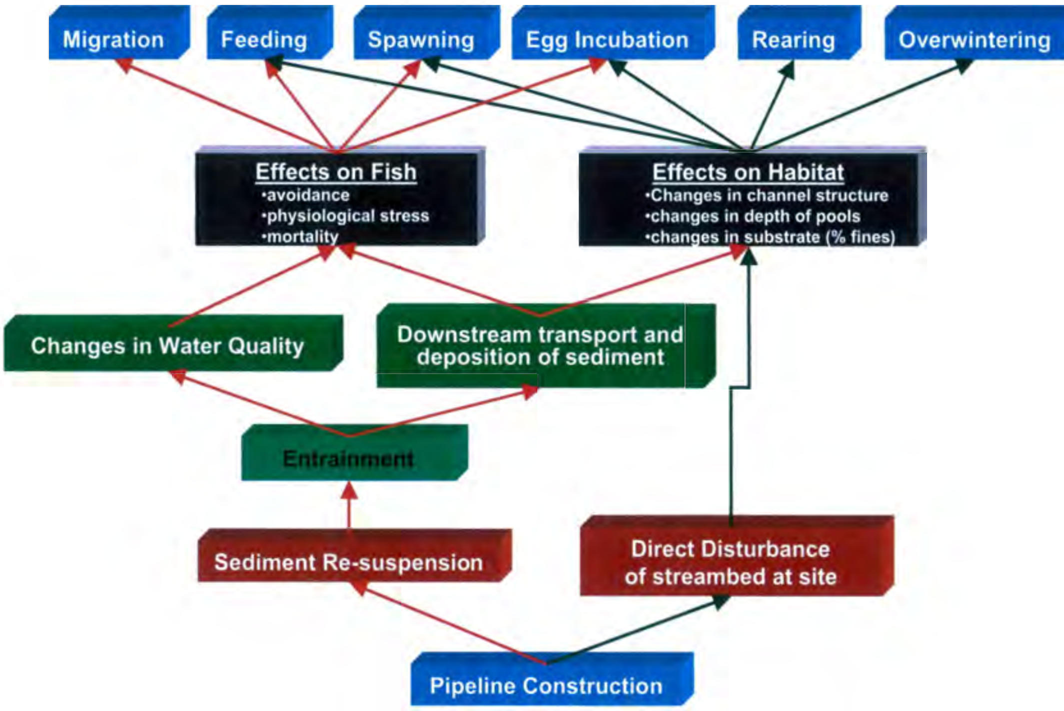

Fig. 1. Effects of pipeline watercourse crossing construction on fish and fish habitat.

mental benefits of isolated crossing methods. This deficiency is important to address as some methods are applied under the assumption that they will mitigate against environmental damage but also have greater construction complexities, risks, cost and durations of instream activity. A lack of TSS monitoring data has prevented defensible statements to be made regarding the provided level of environmental protection (Mutrie and Scott, 1982; Reid and Anderson, 1999).

The River and Stream Crossings Study was undertaken in order to improve our understanding of the biological effects of sediment released during open-cut pipeline water crossing construction, measure the effectiveness of isolated pipeline water crossing techniques, and develop a defensible sediment effects assessment framework for open-cut pipeline water crossings. The following paper provides an overview of study findings.

BIOLOGICAL EFFECTS OF OPEN-CUT PIPELINE WATER CROSSING CONSTRUCTION

A review of 27 past monitoring studies of open-cut pipeline crossings indicated that sediment released during instream construction can cause short-term changes to downstream aquatic life and their habitats (Reid and Anderson, 1999). Changes to downstream habitat include sediment deposits in backwater habitats and pools and the infilling or smothering of riffle habitats (Wendling, 1978; Anderson et al., 1998). Measured biological effects include reductions in the abundance and diversity of benthic invertebrate and fish communities (Tsui and McCart, 1981; Schubert et al., 1985; Anderson et al., 1998). Effects typically were limited to several hundred meters downstream and temporary. Full recovery to pre-disturbance conditions was measured within 2 years after construction. In the vicinity of some crossings, backfilling with coarse bed material and opening of the forest canopy resulted in improved streambed conditions and benthic invertebrate productivity (Reid and Anderson, 1999). The duration and downstream extent of such effects is comparable to other activities resulting in short-term sediment release events affecting relatively small areas downstream (Gammon, 1970; Cline et al., 1982; Harvey, 1986). Longer term changes generally result from activities that result in larger sediment deposition events and alter channel morphology and/or flow characteristics (Narf, 1985; Platts et al., 1990; Rathburn and Wohl, 2001).

A number of limitations in our understanding of pipeline crossing effects were also identified. First, most studies had focused on coldwater systems and on the responses of benthic invertebrate communities. Sediment effects on warmwater fish communities or fish behaviour and physiology were not well documented. Secondly, most studies had investigated crossings of small watercourses. Understanding the effects of open-cut crossings on fish and fish habitat in large river systems is important as alternate crossing techniques (e.g., Horizontal Directional Drilled, HDD) that limit sediment release may not be feasible, or are at high risk of failure. Past studies also used a variety of different suspended sediment measurements (e.g. NTU, JTU, mg/L) so that observed levels of effect were not directly comparable. In response to the deficiencies, monitoring studies were undertaken at open-cut crossings of three warmwater streams in the United States and a coldwater river in northern Alberta, Canada. Monitoring studies measured changes to downstream habitat, benthic invertebrates and fish. In addition to these studies, the physiological effects of sediment exposure on rainbow trout (*Oncorhynchus mykiss*) were investigated during two simulated open-cut pipeline water crossings. Results of monitoring studies are discussed in detail in Reid et al. (2002a, 2002b, and 2003).

Effects on warm water streams

Open-cut crossings of three warmwater streams (Big Darby Creek, Ohio, Coxes Creek, Pennsylvania, and Little Cedar River, Iowa) increased downstream mean TSS concentrations by more than 450 mg/L with peak TSS concentrations greater than 1800 mg/L. However, changes to surficial bed material only occurred at a riffle 50 m downstream of the Big Darby Creek line replacements. Increases in the amount fine sediment deposited onto habitats downstream of the Big Darby Creek crossings coincided with shifts in benthic invertebrate density and community structure. Observed increases in oligochaete (aquatic worms) densities and decreases in the numbers of mayflies, stoneflies and caddisflies (EPT taxa) have been reported in other studies of pipeline water crossing construction effects on benthic invertebrates (Tsui and McCart, 1981; Anderson et al., 1998). The short time frame for recovery (1 year) is consistent with previous studies (Reid and Anderson, 1999).

Sediment released during open-cut crossings did not adversely affect downstream warm water fish communities. At riffles downstream of the Big Darby Creek crossing, the post-construction abundance of one state-listed endangered (spotted darter, *Etheostoma maculatum*), and two threatened (Tippecanoe darter, *Etheostoma tippecanoe* and bluebreast darter, *Etheostoma caeruleum*) was unaffected by construction. Downstream of the Coxes Creek and Little Cedar River crossings, the post-construction abundance of other benthic fish species such as mottled sculpin (*Cottus bairdi*) (Coxes Creek), banded darter (*Etheostoma zonale*) and fantail darter (*Etheostoma flabellare*) (Little Cedar River) was also unaffected. At Big Darby Creek, the duration of magnitude of increases to downstream suspended sediment concentrations associated with instream construction was similar to natural fluctuations associated with storm or runoff events. Mean TSS concentrations downstream of construction were within the natural range of TSS concentrations for Big Darby Creek during September and October (United States Geological Survey 1992 to 1997: 1 to 844 mg L-1). Large reductions in the abundance of benthic fish species such as sculpin and darters have been linked to increases in sediment loading as a result of agricultural activities, housing, logging, mining and road construction (Burns, 1972; Branson and Batch, 1972; Petrosky and Waters, 1975; Barton, 1977; Berkman and Rabeni, 1987). Large reductions in the occurrence of benthic fish species likely requires a greater degree of habitat alteration (i.e., smothering of riffles by sediment) and/or a more prolonged exposure to turbid water than that measured downstream of these water open-cut crossings.

Post-construction changes in the abundance of certain cyprinid (e.g. silver shiner, *Notropis photogenis* and spotfin shiner, *Cyprinella spiloptera*), catostomid (e.g. golden redhorse, *Moxostoma erythrurum*) and centrarchid species (smallmouth bass, *Micropterus salmoides* and longear sunfish, *Lepomis megalotis*) residing in run habitats occurred both upstream and downstream of the Little Cedar River and Big Darby Creek crossings. These shifts were interpreted to reflect of natural daily and seasonal movements. Despite the fact that pipeline construction in Big Darby Creek and the Little Cedar River resulted in equal or greater levels of sediment generation, the absence of effect on warm water fish abundance residing in downstream run and pool habitats contrasts with the Schubert et al. (1985) study of open-cut crossings of the Little Miami River, Ohio. Downstream seine haul catches of the dominant fish species (silver shiner) dropped by 95% immediately after construction and were 50% of pre-construction levels within a month.

Direct effects on fish

Limited success recapturing tagged fish and the absence of control data have prevented defensible statements regarding fish movement and changes in abundance downstream of pipeline water crossing construction. For 22 days, we tracked the movements of radio-tagged Arctic grayling and mountain whitefish before, during and after the open-cut installation of a natural gas pipeline underneath the Wildhay River, Alberta. During trenching, mean TSS concentrations 50 and 150 m downstream were 136.5 and 161.8 mg/L, respectively. Mean TSS concentrations during backfilling ranged between 38.26 and 58.6 mg/L. Turbid water was observed more than 3 km downstream. Radio tagged fish were often sedentary (40% of daily observations). Most of the daily movements occurred within the first three to four days after surgical implantation of radio-transmitters. Since there was no identifiable avoidance pattern by fish relative to increased sediment load, the few movements by downstream fish related to construction were probably motivated by disturbances such as blasting or equipment movement. The absence of avoidance response is attributed to the relatively low suspended sediment concentrations during construction, a lack of habitat alteration, and natural events (spring run-off or storm events) causing equal or greater periods of sediment exposure.

Outside of laboratory studies, little effort has been made to measure the physiological effects of elevated TSS on fish. Most field studies have instead focused on habitat alteration and changes to benthic invertebrate and fish communities (Waters, 1995). We measured the physiological response of caged rainbow trout downstream of two simulated open-cut crossings. TSS concentrations measured downstream of simulated open-cut pipeline water crossings were within the range of values reported by past monitoring studies. For both crossings, mean downstream TSS concentrations increased by 55 to 70 mg/L with peak concentrations greater than 450 mg/L. Trout held in cages downstream of construction had increased respiration rates and shorter times till loss of equilibrium during sealed jar bioassays. Differences in blood hematocrit levels between experiments and transects was attributed to sediment concentration and particle size. Sediment exposure did not result in gill damage or fish mortality. Responses measured were consistent with the level of effect (increased respiration and short-term changes to blood parameters) predicted by the juvenile and adult salmonid dose-response equation (Newcombe and Jenson, 1996).

EFFECTIVENESS OF ISOLATED CROSSING METHODS

Generally, it is assumed that sediment release can be avoided or minimized through the selection of appropriate crossing methods, limiting the duration of instream work, and through the use of Best Management Practices (BMPs). Permitting approval typically is simpler for trenchless crossing methods such as HDD. Although HDD installations do not generate major sediment discharges and avoid disturbance of riparian vegetation, the potential for environmental damage due to unexpected releases of drilling mud still exists (Reid and Anderson, 1998b). As part of a case-history review, Harder (1994) reported that drilling mud releases occurred during 13 of 30 HDD crossings. Secondly, construction related factors such as pipe diameter, thickness and curvature, valley geometry, and subsurface geology can prevent the application of this technique. Therefore, the need for alternate construction methods exists. Isolated (dry) crossing methods such as the dam and pump and flume methods have been developed to limit the amount of sediment released during construction. Dams isolate the instream work area and water is diverted around the work area through a flume and/or pumps. Trench excavation and backfilling occurs under relatively dry conditions thereby limiting downstream sediment loading. A lack of suspended sediment and associated biological effects monitoring during open-cut and isolated water crossings has prevented defensible statements to be made regarding the level of environmental protection provided by isolated crossing methods. A summary of construction details and environmental considerations for open-cut and isolated crossing methods is presented in Table 1. We investigated the effectiveness of isolated crossing methods through: (1) an analysis of TSS monitoring data collected during the construction of 46 pipeline water crossings (23 dam and pump crossings; 12 flumed crossings, and 11 open-cut crossings); and, (2) biological monitoring studies of isolated crossings of three brook trout (*Salvelinus fontinalis*) streams. More detailed discussions of these studies can be found in Reid et al. (2002b and 2004).

Table 1. Overview of construction details and environmental considerations for open-cut and isolated pipeline water crossings

Crossing method	Construction details	Environmental considerations
Open-cut	Trench excavated and backfilled without diversion of flow; equipment typically operates from each bank with spoil stored at upland locations; large watercourses may require instream equipment and spoil storage; typical equipment: hoe, dragline and suction dredge.	Potential adverse effects on downstream aquatic biota and habitats due to sediment entrainment and deposition; sediment entrainment increased by instream spoil storage and equipment activity; as compared to isolated methods, open-cut crossings minimize the period of instream activity; maintains fish passage and streamflow; banks and riparian vegetation require restoration.
Flumed	Dams isolate the instream work area and flow is diverted through a pipe (flume); turbid ditch water pumped to upland sumps; best suited for watercourses with flows $<1\ m^3/s$, non-permeable substrates, and well-defined banks; typical equipment and materials: hoe, sandbag or aqua-barrier dams, flume; for larger watercourses ($<6\ m^3/s$), a superflume (2 m × 3 m × 32 m flume) with aqua-barriers suitable.	Sediment entrainment low and restricted to the installation and removal of dams and flume; effectiveness dependent on proper materials and application; longer period of instream activity than open-cut crossings; fish salvage within dewatered area may be required; no fish passage during period of instream activity; banks and riparian vegetation require restoration.
Dam and pump	Dams isolate the instream work area and bypass pumps maintain downstream streamflow; turbid ditch water pumped to upland sumps; best suited for watercourses with flows $<1\ m^3/s$, non-permeable substrates and well-defined banks; better suited for meandering channels and uneven streambeds than flumed crossing; typical equipment and materials: hoe, sandbag or aqua-barriers, steel plates, bypass pumps and hoses.	Sediment entrainment low and restricted to the installation and removal of dams; effectiveness dependent on proper materials and application; longer period of instream activity than open-cut crossings; fish salvage within dewatered area may be required; no fish passage during period of instream activity; banks and riparian vegetation require restoration.

Table 2. Mean (SE) values for monitoring data used in MANOVA/ANOVA analysis of different crossing methods

Variable	Open-cut ($n = 11$)	Crossing method Flumed ($n = 12$)	Dam and pump ($n = 23$)	ANOVA results
Mean TSS (mg/L)	2663.1 (1157.5)^A	99.1 (42.8)^B	22.7 (5.0)^C	$P < 0.001$
Mean Trench TSS (mg/L)	3501 (1357.8)^B	32.7 (23.5)^A	13.5 (2.8)^A	$P < 0.001$
Mean Backfill TSS (mg/L)	2651 (1083.2)^A	302.6 (122.6)^B	7.5 (1.0)^C	$P < 0.001$
Peak TSS (mg/L)	6654.8 (833.1)^A	2008.0 (3228.0)^A	334.0 (23.0)^B	$P = 0.001$
Distance downstream (m)	50.3 (6.6)	52.8 (10.2)	52.5 (6.3)	n.s.
Hours instream (hrs)	13.7 (2.0)^C	64 (14.1)^A	37.8 (8.4)^B	$P < 0.001$
Background TSS (mg/L)	16.1 (5.02)	3.9 (0.6)	6.9 (1.9)	n.s.
Discharge (m^3/s)	0.55 (0.15)^A	1.1 (0.4)^A	0.1 (0.04)^B	$P < 0.001$

Note: For individual variables, letters indicate crossing methods that are statistically different (i.e. A and B indicate statistically different values). Tukey HSD Test Significance level: $p < 0.05$.

Sediment entrainment

The three crossing methods (open-cut, dam and pump and flumed) entrained different amounts of sediment during construction (MANOVA: $p < 0.0001$, Table 2). Ninety percent of the dam and pump and fifty percent of the flumed crossings limited increases in mean TSS concentrations to less than 25 mg/L above background levels. Only 2 of the 12 flumed crossings resulted in increases more than 80 mg/L above background levels. Sediment release during isolated pipeline crossings was generally restricted to short-term peaks associated with the installation and removal of isolation and bypass structures. However, isolated pipeline crossings were 3 to 5 times longer in duration than open-cut crossings. Open-cut crossings of small to medium sized watercourses typically were completed in 1 to 2 days. Mean TSS concentrations during all phases of open-cut crossings were significantly higher than flumed and dam and pump crossings. While both the flumed and dam and pump crossing methods were equally effective at limiting sediment release during trenching, mean TSS concentrations measured during backfilling of flumed crossings were significantly higher (303 vs. 7.5 mg/L). Although the peak TSS concentrations associated with open-cut crossings were on average 3 and 20 times greater than flumed and dam and pump crossings (respectively), the difference between open-cut and flumed crossings was not significant. Some of the variation in TSS concentrations between crossing methods may reflect differences in flow. Discharge and each of the TSS variables were weakly correlated (r^2: 0.1 to 0.57). Correlations can be explained by the application of the dam and pump crossing method to smaller watercourses (mean stream flow rate: 0.1 m^3/s) than either flumed or open-cut methods, which both entrained more sediment during instream construction.

The effectiveness of isolated crossing methods is dependent on proper design and application. Reported construction related difficulties include: (1) pump failure or insufficient capacity; (2) dam or flume failure; (3) poor dam seal; (4) poor containment of pumped ditch water; and (5) inadequate maintenance of sediment control measures. During dam and pump crossings, construction related difficulties that resulted in large increases to downstream TSS concentrations were rare (1 of 23 crossings). Alternatively, such difficulties resulted in large increases in downstream TSS concentrations (60 to 1848 mg/L) during 5 of the 12 flumed crossings. Poor containment of pumped ditch water and poor dam seals were the causes. Flumed crossings are often applied to larger watercourses than dam and pump crossings. Larger water crossings require longer periods of instream activity and the control of larger volumes of both streamflow and trench water. Both characteristics increase the risk of sediment being released into the watercourse (Reid et al., 2002a; 2002b). The type of material used to isolate the instream work area during flumed crossings influenced the level of sediment entrainment. Concrete jersey barriers with sandbags and plastic sheeting were effective at minimizing sediment release during flumed crossings of small watercourses (discharge <0.3 m^3/s). However, for larger watercourses with unconsolidated bed material (e.g. gravel and cobble), higher flows can readily erode bed material underneath concrete jersey barriers and allow water to pass through the instream work area. For example, during the flumed crossing of Big Darby Creek, Ohio, dam failure resulted in mean downstream TSS concentrations of 1500 mg/L during backfilling (Reid et al., 2002c). In Alberta, aqua-barriers have been effective at isolating the instream work area during superflume crossings of medium-sized watercourses (<6 m^3/s) with unconsolidated bed material and sensitive coldwater fisheries (Reid and Anderson, 2002).

Mitigation of adverse effects

Summer pipeline installation across six brook trout streams (1 to 8 m wide) provided an opportunity to evaluate the effectiveness of isolated crossing methods to limit the amount of sediment released during instream construction and associated effects on downstream fish and fish habitat. Brook trout streams are excellent study systems to evaluate isolated crossing methods. They are a widespread and valued sport-fish, and the vulnerability of brook trout to sediment induced habitat alteration is well documented (Anderson et al., 1998). Compared to open-cut pipeline crossings of other similar sized watercourses, increases to mean downstream TSS concentrations during dam and pump or flumed crossings were at least seven times lower. Except for during one of the flume crossings, mean TSS concentrations averaged only 3 to 20 mg/L above background levels. Alternatively, mean downstream TSS concentrations of open-cut crossings of similarly sized watercourses were 600 to 1300 mg/L above background. Peak TSS concentrations measured downstream of isolated crossings were also lower than open-cut crossings and were generally restricted to the installation and removal of isolation and diversion structures. While mean TSS concentrations were lower during the six isolated crossings, the average duration of instream construction was up to seven times that of open-cut crossings. Increased sediment deposition was measured immediately downstream (<50 m) of two of the crossings. However, pebble count data indicated that surficial bed material downstream of all the crossings was unaffected. Despite a lack of prolonged exposure to high suspended sediment concentrations or habitat alteration caused by sediment deposition, lower post-construction fish abundance was measured downstream of three of the crossings. Reductions in abundance resulted from either temporary reductions in water level when bypass pumps were moved, or natural variation in flow levels after construction. The effectiveness of isolated crossing methods to limit sediment release and associated habitats effects is consistent with the findings of Reid and Anderson (2002). During winter pipeline installation under 17 watercourses that supported sensitive coldwater fish populations (i.e., Arctic grayling and mountain whitefish), dam and pump and flumed crossing methods were effective at limiting sediment release and avoiding adverse downstream habitat alteration.

SEDIMENT EFFECTS ASSESSMENT FRAMEWORK

Open-cut methods may often be the only feasible crossing construction alternative. Therefore, it is important that pipeline construction and resource managers are able to make defensible assessments of downstream effects associated with various crossing methods. In the past, crossing assessments have relied heavily upon expert opinion, anecdotal information and worst case scenarios, despite progress made towards understanding the effects of sediment on fish and aquatic habitats (Anderson et al., 1996; Newcombe and Jensen, 1996). At present, there are few quantitative tools for effects assessment of pipeline water crossing construction on fish and fish habitat. This situation is typical for many anthropogenic activities affecting fish habitat (Minns, 2001). We developed a sediment-effects assessment framework for pipeline construction and resource managers to use during construction planning (Fig. 2). The framework applies readily available or measurably information about the watercourse and crossing method to estimate risks to down-

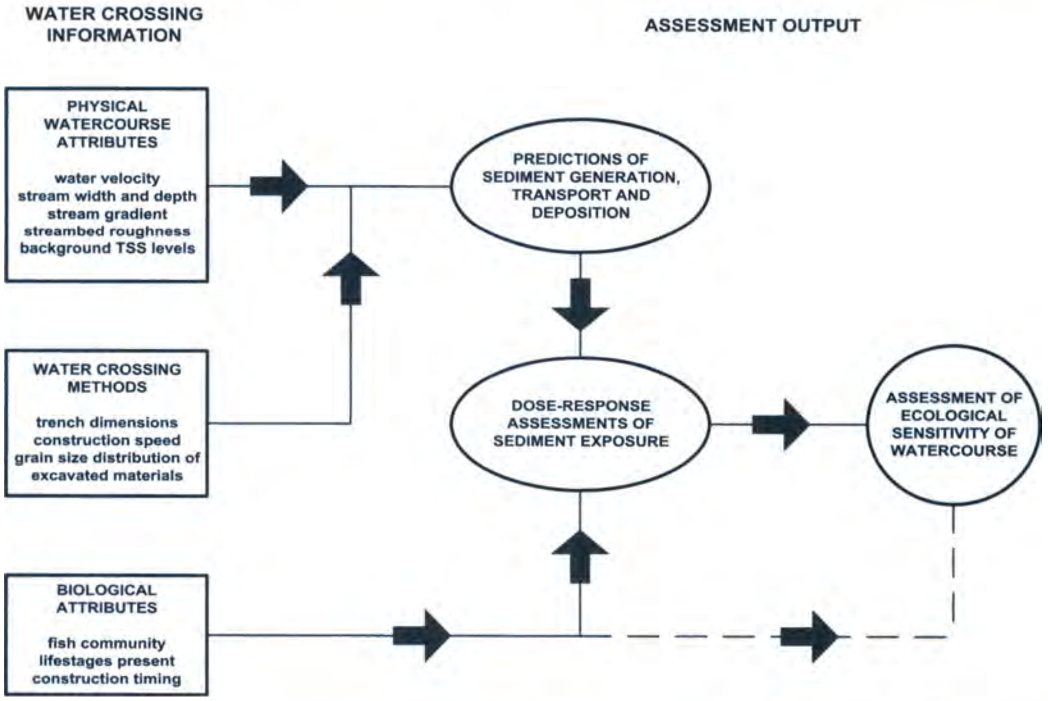

Fig. 2. Flow diagram of assessment pathway applied to evaluate the ecological sensitivity of the watercourse to open-cut pipeline water crossings.

stream fish communities associated with sediment entrained during crossing construction. Output includes estimates of downstream suspended sediment concentrations and sediment deposition rates; and, dose-response based assessments of the sensitivity of downstream fish and their habitats. The framework was used to develop CROSSING™ is a Microsoft Windows based software application.

Sediment entrainment and transport

Past TSS monitoring studies were used to derive equations for prediction of sediment entrainment rates during different phases of open-cut crossing construction (Table 3). Sediment entrainment predictions are based on the flow and bed material characteristics of the watercourse. An empirical modelling approach was selected as model formulation based on partial differential equations for modelling turbulent flows and sediment entrainment was considered too complex for practical application. Secondly, our goal was to derive equations that could be applied using readily available or obtainable measurements of watercourse conditions. As the equations were derived from a wider range of bed material sizes and without calibration factors, they are considered to represent a substantial improvement over previous models (Trow, 1996; Long et al., 1998). Data collection and model development are described in Reid et al. (2004).

Higher correlation coefficients and smaller differences between predicted and measured rates indicate that estimates of sediment entrainment rates for the entire crossing period (All Activities) and during trench excavation (Trenching) are more accurate than during pipe lowering or backfilling (Table 3). In order to validate the models, we simulated open-cut pipeline watercourse crossing at Serviceberry Creek, Alberta and Conestogo River, Ontario. For both the Serviceberry Creek and Conestoga River simulated pipeline crossings, mean TSS equations more closely predicted measured downstream TSS concentrations than peak TSS equations (3 to 81% vs. 23 to 551% percent difference, or 3 to 154 mg/L vs. 184 to 5004 mg/L). For all activities combined, the predicted mean TSS concentrations were less than 16 mg/L (3 to 5%) above measured concentrations. As the models are empirical, they are best applied within the following range of site and construction conditions:

1. stream flow rate (m^3/s): $0.30 < Q < 190$;
2. percentage of fines (silt and clay) (P_f): $5\% < P_f < 66\%$;
3. backhoe bucket size: 1.5 to 1.6 m^3; and
4. trenching or backfilling rate: 2 to 3 buckets per minute of activity.

Predicted sediment entrainment rates are then used to calculate mean suspended sediment concentrations and sediment deposition rates downstream of the crossing. Sediment transport is a function of particle size, channel morphology and flow characteristics such as velocity. Downstream suspended sediment concentrations and sediment deposition rates are based on Rubey's approach for predicting sediment particle fall velocities and 1-dimensional CREAMS and WEPP sediment transport models (Foster et al., 1980; Storm et al., 1994; Flanagan and Livingston, 1995). Based on monitoring data, the entrainment and transport modelling approach appears to capture the range of sediment entrainment and transport behaviour (Fig. 3). Improvements to sediment transport predictions could be achieved independent by using other

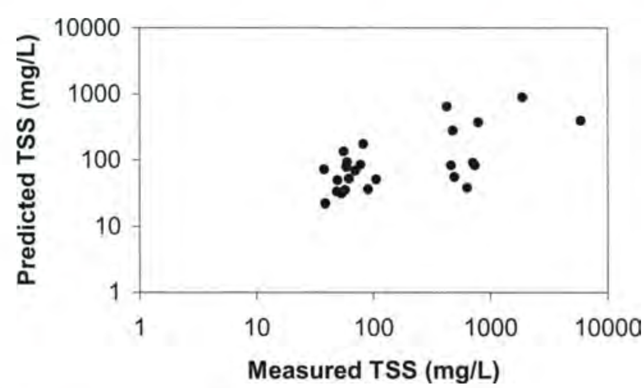

Fig. 3. Comparison of measured and predicted TSS concentrations measured 50 to 1650 m downstream of 14 open-cut pipeline water crossings (Spearman Rank Correlation, $r_s = 0.59$; $p < 0.002$) (S. Reid unpublished data).

Table 3. Sediment entrainment models for predicting mean (C_{av}) and peak (C_p) TSS concentrations immediately downstream of pipeline water crossing construction

Construction activity	Parameter	Equation	r^2	Mean percent difference (range)
All activities	Mean TSS	C_{av} = 1.5E6 U1.09d_{50}0.95P_f2.35q-1	0.65	106 (11–505)
	Peak TSS	C_p = 5.7E5 U1.86d_{50}0.57P_f1.2q-1	0.36	85 (13–312)
Trenching	Mean TSS	C_{av} = 4.53E6 U d_{50} P_f2.77q-1	0.7	107 (4–312)
	Peak TSS	C_p = 1.05E6 U1.67d_{50}0.67P_f1.65q-1	0.51	78 (3–286)
Pipe lowering	Mean TSS	C_{av} = 3.84E5 U1.15d_{50}0.93P_f2.3q-1	0.45	181 (30–528)
Backfilling	Mean TSS	C_{av} = 6.95E5 U1.54d_{50}0.73P_f2.44q-1	0.34	107 (4–312)
	Peak TSS	C_p = 4.95E6 U2.08d_{50}0.46P_f1.6q-1	0.05	132 (2–441)

Note: C_{av} is the mean suspended sediment concentration (mg/L); U is the mean flow velocity (m/s); d_{50} is the median particle size of excavated material (m); P_f is the percent of excavated material consisting of silt or clay; and, q is the width adjusted stream flow rate (m^2/s). Differences between measured and predicted concentrations are based on the original dataset used to derive entrainment models.

Table 4. Comparison of predicted SEV for downstream fish and past pipeline water crossing monitoring studies

Watercourse	Duration (hr)	SS (mg/L)	SEV	Predicted effect	Measured effect	Reference
Big Darby Cr., OH	39.5	629	8.5	Avoidance behaviour Major physiological stress	No effect on warmwater fish abundance or community structure	Reid et al., 2002a
Little Cedar R., IO	27	451	8.2	Avoidance behaviour Major physiological stress	No effect on warmwater fish abundance or community structure	Reid and Metikosh, 2001
Coxes Cr., PA	12	781	7.5	Avoidance behaviour Moderate physiological stress	No effect on coldwater fish abundance or community structure	Reid and Metikosh, 2001
Findley Cr., ON	7	1679	7.7	Avoidance behaviour Major physiological stress	Temporary (<1 yr) reduction in brook trout abundance	Anderson et al., 1998
Little Miami River, OH	48	1461	8.9	Avoidance behaviour Major physiological stress	Temporary (<1 yr) reduction in warmwater fish abundance	Schubert et al., 1985
Wildhay R., AB	52	135	7.1	Avoidance behaviour Major physiological stress	No effect on mountain whitefish and arctic grayling movements or abundance	Reid et al., 2002b
Serviceberry Cr., AB	30.7	297	7.3	Moderate physiological stress	Increased rainbow trout respiration rate	Reid et al., 2003
Conestoga R., ON	28.9	115	6.6	Moderate physiological stress	Increased rainbow trout respiration rate Altered rainbow trout blood chemistry	Reid et al., 2003

sediment transport models (e.g. HEC-2) that incorporate information such as gradient and more detailed descriptions of channel morphology. More complex models were not selected because of the limited amount of flow and channel morphology data typically available.

Sediment effects assessment

Sediment-effects assessment is primarily based on the output of sediment entrainment and transport predictions and dose-response equations developed by Newcombe and Jensen (1996) and Newcombe (1998). Dose-response equations were derived from a meta-analysis of published laboratory and field studies investigating sediment effects. A severity of ill effect (SEV) scoring system was identified to represent the magnitude of biological response of fish and benthic invertebrates (e.g. stoneflies and mayflies) to sediment exposure. As SEV is a function of the duration and magnitude of suspended sediment exposure (DOSE), the graded scale permits the identification of qualitative increases in the severity of effect as the magnitude and duration of exposure increases.

Dose-response equations were developed from studies of several different taxonomic (salmonid, freshwater non-salmonid and estuarine non-salmonid species) and life-stage groupings (eggs and larvae, juveniles, and adults). The number of data points used to develop individual equations was biased to salmonids because of a limited dataset for non-salmonid species. Correspondingly, effect assessment is expected to be more accurate for watercourse supporting coldwater fish communities than warmwater or estuarine systems (Wilbur and Clarke, 2001). Secondly, case studies investigating the effects of pipeline water crossing construction were not included in the dataset used to develop dose-response equations (Newcombe and Jenson, 1996). Recent evaluations of the response of coldwater species (i.e. salmonid species) downstream of open-cut pipeline water crossings indicate that these equations accurately predict the occurrence of minor to moderate levels of physiological stress (e.g. altered blood chemistry) (Table 4). At lower exposure levels, dose-response equations may overestimate the likelihood of less severe stress responses (e.g. altered habitat use and avoidance of turbid plumes) (Table 4). Wilbur and Clarke (2001) contend that for motile organisms, such as fish, exposure duration is probably limited to minutes or hours. However, biological effects monitoring studies of open-cut crossing construction suggest that exposure to elevated suspended sediment concentrations alone is insufficient to motivate downstream fish to avoid the plume of turbid water (Reid et al., 2002b). Instead, fish population or community changes are dependent on substantial changes to downstream habitat conditions such as smothering of riffles or infilling of pools (Reid and Anderson, 1999).

While short-term (i.e. hours) increases in rates of benthic invertebrate drift may occur in response to elevated TSS concentrations (Young and Mackie, 1990), reductions in the abundance and community structure of benthic invertebrate communities also appear to be dependent on sediment deposition caused habitat alteration. Results from nine studies that monitored benthic invertebrate community responses to elevated TSS concentrations downstream of pipeline construction were used to evaluate the benthic invertebrate SEV equation (Table 5). SEV scores (8 to 12.4) correctly

Table 5. Comparison of predicted SEV for downstream benthic invertebrates and past pipeline water crossing monitoring studies

Watercourse	Duration (hr)	SS (mg/L)	SEV	Predicted effect	Measured effect	Reference
Big Darby Cr., OH	39.5	629	11	Reduced abundance (20–40%) and species diversity	Temporary (<1 yr) reduction in abundance and species diversity	Reid et al., 2002a
Findley Cr., ON	7	1679	10.9	Reduced abundance (0–20%) and species diversity	Increased drift during construction Temporary (<1 yr) reduction in species diversity	Anderson et al., 1998
Little Cedar River, IO	27	451	10.5	Reduced abundance (0–20%) and species diversity	No effect	Reid and Metikosh, 2001
Archibald Cr., BC	20	6247	12.4	Reduced abundance (40–60%) and species diversity	Temporary (<1 yr) reduction in abundance	Tsui and McCart, 1981
Little Miami River, OH	48	1461	11.7	Reduced abundance (20–40%) and species diversity	Temporary (<1 yr) reduction in abundance and species diversity	Schubert et al., 1985
Black R., NY	12.4	44	8.0	Temporary change in community structure	Temporary (<1 yr) reduction in abundance	Cerretani, 1991
Bow R., AB	120	83	10.1	Reduced abundance (0–20%) and species diversity	Temporary (<1 yr) reduction in abundance and species diversity	Kraft, 1981
Hodgson Cr., NWT	6	997	9.3	Temporary change in community structure	Increased drift during construction No effect on abundance or community structure	Young and MacKie, 1990
Canada Cr., MI	7	426	9.9	Temporary change in community structure	No effect	Vinikour and Schubert, 1987

predicted reductions in abundance, or shifts in community structure in seven crossings. In contrast to the other studies, the two open-cut crossings that did not affect downstream benthic invertebrate communities also did not alter downstream habitats.

Increased rates of sediment deposition can also adversely alter fish habitat through the infilling of pools and the smothering of riffle habitats (Anderson et al., 1996). The nature of downstream habitat alteration is dependent on the amount and particle size of deposited sediment, the characteristics of the affected habitats and the timing of sediment deposition. If the distance downstream of potentially sensitive habitats (e.g. trout spawning habitat, or over-wintering pools) are known, the risk of habitat alteration can be assessed. Also, predictions could be used to define the downstream boundaries of habitat investigations of the watercourse to be crossed. In its current form, the framework does not provide predictions of specific habitat changes (e.g. increase in percent fines of 10%) or the duration of effect (i.e. recovery timeframe). More detailed modelling of potential sediment deposition effects on riffle and run habitats can be attempted using relationships presented by Lisle (1989) and more detailed on site habitat information. Determination of flows and timeframe required to flush out deposited sediment can be based on equations derived by Milhous (1989), Shield's relation, estimated return periods of bankfull discharge levels and flow exceedence curves.

CONCLUSIONS

The River and Stream Crossings study was successful at improving our understanding of the effects of sediment released during pipeline water crossing construction; effectiveness of isolated crossing methods to minimize sediment release; and developing a sediment effects framework for pipeline water crossings. Effects on fish and fish habitat due to open-cut crossing construction were found to be generally limited to increased sediment deposition and short-term habitat alteration within a short distance downstream. Monitoring data supported the assumption that isolated crossing methods are effective at limiting sediment release and avoiding adverse downstream habitat alteration. However, the effectiveness of isolated crossing methods is strongly dependent on proper design and application. New equations for the estimation of downstream peak and mean suspended sediment concentrations during open-cut crossing construction were derived from suspended sediment monitoring data. An assessment framework (CROSSING^{TM}) using entrainment equations and dose-response equations was found to provide biologically realistic predictions of effect.

Planning of pipeline water crossings would further benefit from continued research in the following areas. Continuous improvement of crossing construction practices is a key component of the environmental protection of streams and rivers. Therefore, ongoing monitoring using a standardized protocol (Reid et al., 2002d) is essential for the defensible performance measurement of new construction methods and materials or the application of previously successful approaches to different construction conditions. The collection of additional open-cut crossing TSS monitoring data outside the physical conditions used to develop sediment entrainment equations would is required to validate their generality. Lastly, biological effects assessment in the presented framework is based on downstream TSS concentrations and dose-response equations. While downstream sediment deposition rates can be predicted, current science does not permit a similar linkage between sediment deposition, habitat characteristics and thresholds of biological response. Some progress has been made to model deposition caused habitat changes (Lisle, 1989) and a large number of studies have documented biological responses to increased deposition. However, before defensible predictions can be made, existing relationships predicting physical habitat alteration need to be expanded and the large number of biological effects case studies needs to be synthesized. The later step is likely to be very difficult as a wide variety of incompatible approaches have been used in past studies to measure habitat changes.

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REFERENCES

Anderson, P.G., B.R. Taylor, and G.C. Balch. 1996. Quantifying the effects of sediment release on fish and their habitats. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2346. 110 pp.

Anderson, P.G., C.G.J. Fraikin, and T.J. Chandler. 1998. Natural gas pipeline crossing of a coldwater stream: impacts and recovery. In: Proceedings of the International Pipeline Conference 1998. American Society of Mechanical Engineers. Calgary, Alberta. June 7–11, 1998. pp. 1013–1022.

Barton, B.A. 1977. Short-term effects of highway construction on the limnology of a small stream in southern Ontario. Freshwater Biology, 7: 99–108.

Berkman, H.E. and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biology of Fishes, 18: 285–294.

Branson, B.A. and D.L. Batch. 1972. Effects of strip mining on small-stream fishes in east-central Kentucky. Proceedings of the Biological Society of Washington, 84: 507–518.

Brown, C.M., R.D. Revel, and J.R. Post. 2002. Effects of pipeline rights-of-way on fish habitat at two Alberta stream crossings. In: Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. Elsevier Science Ltd. pp. 705–715.

Burns, J.W. 1972. Some effects of logging on and associated road construction on northern California streams. Transactions of the American Fisheries Society, 101: 1–17.

Cerretani, D.G. 1991. Sampling results of the underground crossing of Black River. NYSEG R&D Project 150.51.60.

Cline, L.D., R.A. Short, and J.V. Ward. 1982. The influence of highway construction on the macroinvertebrates and epilithic algae of a high mountain stream. Hydrobiologia, 96: 149–159.

Flanagan, D.C. and S.J. Livingston (ed.). 1995. Water erosion prediction project (WEPP) user summary, National Soil Erosion Research Laboratory, West Lafayette, IN.

Foster, G.R., L. Lane, J.D. Nowlin, J.M. Laflen, R.A. Young, S.J. Smith, D.E. Kissel, and J.R. Williams. 1980. Chemicals, runoff and erosion from Agriculture Management Systems (CREAMS), United States Department of Agriculture in Conjunction with the Science and Education Administration-Agriculture Research (SEA-AR).

Gammon, J.R. 1970. The effect of inorganic sediment on stream biota. EPA, Water Pollution Control Research Series No. 18050 DWC 12/70. Water Quality Office, Washington, D.C.

GRI 2001e. Short-term effects of pipeline water crossing construction on the Little Cedar River, Iowa and Coxes Creek, Pennsylvania. Topical Report GRI-01/0037 Gas Research Institute, Chicago, Illinois.

Harder & Associates Ltd. 1994. Case history review of directional drill projects for water crossings. Report prepared for West Coast Energy Inc.

Harvey, B.C. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. North American Journal of Fisheries Management, 6: 401–409.

Kraft, L.F. 1981. Aquatic ecosystems investigations in relation to the Alaska Highway gas pipeline crossings of the Bow and Red Deer rivers, Alberta. 1980. Vol. 1. Report prepared by Environmental Management Associates.

Lisle, T.E. 1989. Sediment transport and resulting deposition in spawning gravels, North Coastal California. Water Resources Research, 25: 1303–1319.

Long, D., M.J. Bender, L.F. Sawatsky, P. Anderson, and S. Metikosh. 1998. Sediment entrainment during construction of river pipeline crossings: occurrence, prediction and control. Proceedings of the International Pipeline Conference, American Society of Mechanical Engineers, Calgary, Alberta, June 10–14, 1998. pp. 1045–1050.

Milhous, R.T. 1989. Physical habitat simulation and sedimentation. International Association of Hydrological Sciences.

Minns, C.K. 2001. Science for freshwater fish habitat management in Canada: current status and future prospects. Aquatic ecosystem health and management, 4: 423–436.

Mutrie, D.F. and I.F.H. Scott. 1982. Environmental evaluation of water crossing techniques for pipeline construction in Canada. In: Third International Symposium on Environmental Concerns in Rights of Way Management. February 15–18, 1982. San Diego, CA. Mississippi State University Press, 1984.

Narf, R.P. 1985. Aquatic insect colonization and substrate changes in a relocated stream segment. Great Lakes Entomologist, 18: 83–92.

Newcombe, C.P. 1998. Mining and fisheries. Sediment impact models. Mine Reclamation and Remediation Symposium, Penticton, British Columbia. September 14–17, 1998.

Newcombe, C.P. and J.O. Jenson. 1996. Channel TSS and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management, 16: 693–727.

Petrosky, C.E. and T.F. Waters. 1975. Annual production by the slimy sculpin population in a small Minnesota trout stream. Transactions of the American Fisheries Society, 104: 237–244.

Platts, W.S., R.J. Torquermada, M.L. McHenry, and C.K. Graham. 1990. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Fisheries Society, 118: 274–283.

Rathburn, S.L. and E.E. Wohl. 2001. One-dimensional sediment transport modeling of pool recovery along a mountain channel after a reservoir sediment release. Regulated Rivers: Research and Management, 17: 251–273.

Reid, S.M. and P.G. Anderson. 1998a. Suspended sediment and turbidity restrictions associated with instream construction activities in the United States: an assessment of biological relevance. Proceedings of the International Pipeline Conference, American Society of Mechanical Engineers, Calgary, Alberta, June 10–14, 1998. pp. 1035–1040.

Reid, S.M. and P.G. Anderson. 1998b. HDD not the answer for all sensitive water crossings. Environmental effects of mud releases need further study to improve crossing method selection and best management practices. Pipeline and Gas Industry, 81(7): 55–65.

Reid, S.M. and P.G. Anderson. 1999. Effects of sediment released during open-cut pipeline water crossings. Canadian Water Resources Journal, 24: 23–39.

Reid, S.M. and P.G. Anderson. 2002. Evaluation of isolated watercourse crossings during winter construction along the Alliance Pipeline in northern Alberta. 7th International Symposium on Environmental Concerns in Rights-of-Way Management. Calgary, Alberta. Elsevier Science. pp. 735–742.

Reid, S.M. and S. Metikosh. 2001. Short-term effects of pipeline water crossing construction on the Little Cedar River, Iowa and Coxes Creek, Pennsylvania. Gas Research Institute Topical Report GRI-01/0037.

Reid, S.M., S. Stoklosar, S. Metikosh, T. Huffman, and J.M. Evans. 2002a. Effects of natural gas pipeline water crossing replacement on the benthic invertebrates and fish communities of Big Darby Creek, Ohio. 7th International Symposium on Environmental Concerns in Rights-of-Way Management. Calgary, Alberta. Elsevier Science pp. 717–723.

Reid, S.M., S. Metikosh, and J.M. Evans. 2002b. Movement of Arctic grayling and mountain whitefish during an open-cut pipeline water crossing of the Wildhay River, Alberta. Journal of Freshwater Ecology, 17: 363–368.

Reid, S.M., S. Stoklosar, S. Metikosh, and J.M. Evans. 2002c. Effectiveness of isolated pipeline water crossing techniques to mitigate sediment impacts on brook trout (*Salvelinus fontinalis*) streams. Water Quality Research Journal of Canada, 37: 477–488.

Reid, S.M., A. Jalbert, S. Metikosh, and M. Bender. 2002d. A performance measurement framework for pipeline water crossing construction. 7th International Symposium on Environmental Concerns in Rights-of-Way Management. Calgary, Alberta. Elsevier Science. pp. 697–703.

Reid, S.M., G. Isaac, S. Metikosh, and J.M. Evans. 2003. Physiological response of rainbow trout (*Oncorhynchus mykiss*) exposed to sediment released during open-cut pipeline water crossing construction. Water Quality Research Journal of Canada, 38: 473–481.

Reid, S.M., F. Ade, and S. Metikosh. 2004. Sediment entrainment during pipeline water crossing construction: predictive models and crossing method comparison. Journal of Environmental Engineering and Science, 3: 81–88.

Scubert, J.P., W.S. Vinikour, and D.K. Gartman. 1985. Effects of gas-pipeline construction on the Little Miami aquatic ecosystem. Gas Research Institute Topical Report GRI-86/0024.

Storm, D.E., Barfield, B.J., and C.T. Altendorf. 1994. CREAMS/WEPP sediment deposition equation: a semitheoretical evaluation. Transactions of the American Society of Agricultural Engineers, 37: 1105–1108.

TERA Environmental Consultants (Alta.) Ltd. (TERA). 1996. Water crossing case history review. Prepared for Westcoast Energy.

Trow Engineering Ltd. (TROW). 1996. Canadian pipeline industry sediment transport seminar. 58 p.

Tsui, P.T.P. and P.J. McCart. 1981. Effects of streamcrossing by a pipeline on the benthic macroinvertebrate communities of a small mountain stream. Hydrobiologia, 79: 271–276.

Vinikour, W.S. and J.P. Schubert. 1987. Effects of gas pipeline construction on the aquatic ecosystem of Canada Creek, Presque Isle County, Michigan. Gas Research Institute Topical Report GRI-87/0027.

Waters, T.F. 1995. Sediment in streams. Sources, biological effects and control. American Fisheries Society Monograph 7. Bethesda, Maryland. 251 p.

Wendling, F.L. 1978. Final report on gravel porosity studies along the Trans-Alaska Pipeline. Special Report Number 18. Joint State/Federal Fish and Wildlife Advisory Team.

Wolverton, T. and L.A. Gray. 1997. Lengthy, candid talks result in successful stream crossing. Pipeline and Gas Industry, 80(1): 71–75.

Wilbur, D.H. and D.G. Clarke. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish in relation to dredging activities in estuaries. Transactions of the American Fisheries Society, 21: 855–875.

Young, R.J. and G.L. Mackie. 1990. Effect of oil pipeline construction on the benthic macroinvertebrate community structure of Hodgson Creek, NWT. Canadian Journal of Zoology, 69: 2154–2160.

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Submerged Aquatic Vegetation (SAV) Aerial Hyperspectral Imaging and Groundtruthing Survey: Use of Aerial Hyperspectral Imaging in Defining Habitat Areas of Particular-Concern for Summer Flounder in a High-Energy Estuarine Environment

Aleksandr C. Modjeski

ENSR, in conjunction with Spectrum Mapping LLC, and Barry Vittor and Associates, conducted an SAV Aerial Hyperspectral Imaging and Groundtruthing Survey within Manahawkin Bay, Ocean County, New Jersey in July 2002. The survey was performed to finalize location of a proposed, submerged transmission line within a pre-existing Right-of-Way (ROW), and identify and avoid SAV beds and areas defined as Habitat-Areas of Particular-Concern (HAPC) for summer flounder (*Paralycthes dentatus*). An AISA (Airborne Imaging Spectrometer for Applications) hyperspectral imaging sensor was used to determine presence/absence of SAV beds within a 3.75 sq. mile area; give precise location and extent of identified SAV beds; and calculate percent coverage of identified SAV per meter of each survey site within and adjacent to the proposed submerged cable project. Conventional groundtruthing/field verification methodologies used in Florida, Chesapeake Bay, and New Jersey were combined and modified to increase survey accuracy, increase field efficiency, and provide sufficient data for hyperspectral analysis/verification. Additional groundtruthing data collected at each survey site included: substrate type; vegetation composition; relative health of SAV; blade lengths (when applicable); random stem counts; presence of hard clam (*Mercenaria mercenaria*); and water quality. In addition to the hyperspectral survey, a Braun-Blanquet and hydrographic survey was conducted by Crofton Diving Industries to confirm and further validate hyperspectral results and determine proximity of potential unvegetated SAV habitat to proposed project location.

Keywords: Submerged aquatic vegetation, SAV, eelgrass, aquatic plants, fish, remote sensing, hyperspectral, estuary, water crossings, substrate, GIS, water quality, threatened and endangered species

INTRODUCTION

The Mid Atlantic Fisheries Management Council (MAFMC) designated submerged aquatic vegetation (SAV) and macroalgae beds in nursery habitats as Habitat-Areas of Particular-Concern (HAPC) for juvenile and larval-stage summer flounder (MAFMC, 1998). The Essential Fish Habitat (EFH) Amendment specifically designates summer flounder HAPC as all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations, within adult and juvenile summer flounder EFH. The EFH Amendment notes the importance of the ecological function of these habitat types in providing summer flounder shelter from predators and prey.

Manahawkin Bay, located in Ocean County, New Jersey, is one of the three shallow microtidal bays that comprise the Barnegat Bay-Little Egg Harbor estuarine system (Kennish, M.J., 2001). The Barnegat Bay-

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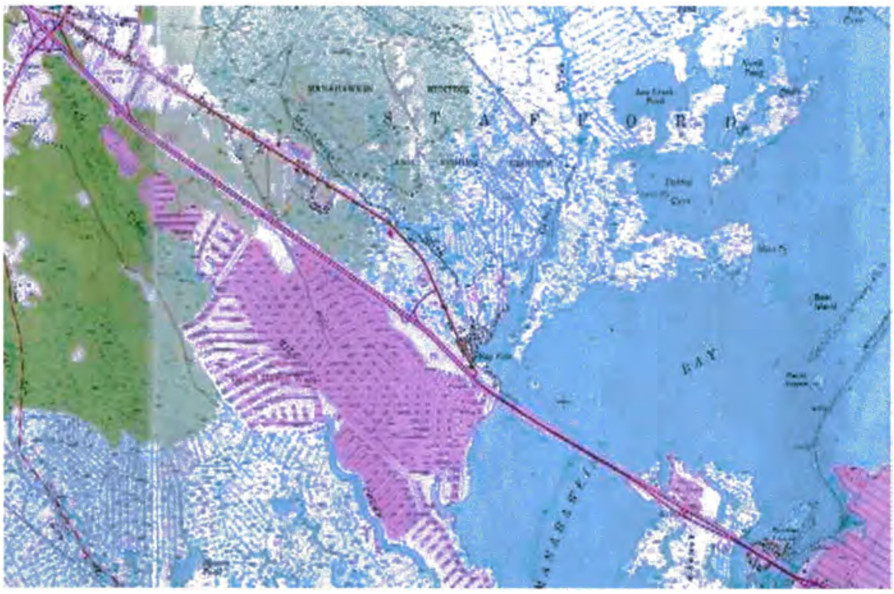

Fig. 1. Project location.

Little Egg estuary consists of three, interconnected bays stretching the majority of the New Jersey coastline. It contains over 75% of New Jersey's seagrasses (Lathrop et al., 1999). In order to deliver needed electricity to the expanding shore community of Long Beach Island, New Jersey, an upgrade to an existing transmission line crossing Manahawkin Bay was proposed. The proposed crossing had been previously mapped as SAV habitat and identified as EFH and HAPC for summer flounder by the National Marine Fisheries Service (NMFS). Mapping completed by the New Jersey Department of Environmental Protection Bureau of Shellfisheries in 1986 and 1987 indicated that Manahawkin Bay's substrate was predominantly SAV. More recent mapping of SAV within Manahawkin Bay revealed a spatial distribution similar to that of areas located in northern Barnegat Bay where the majority of SAV is restricted to subtidal flats at depths less than 1 m (McLain et al., 2001; Bologna et al., 2000; Lathrop et al., 1999; McLain and McHale, 1997). Mapping associated with the aforementioned surveys displayed differences in SAV distribution that may have been attributed to differences in mapping methods or data interpretation. In order to determine precise location of SAV and subsequent HAPC for summer flounder and avoid/minimize impacts associated with the proposed transmission line upgrade, ENSR Corporation was contracted to conduct an SAV aerial hyperspectral and field groundtruthing survey within Manahawkin Bay, New Jersey. Results were mapped with 1-meter accuracy and used to finalize location for submerged cable placement within an existing underwater ROW.

STUDY SITE

The study site was approximately 3.75 square miles (Fig. 1). Separated from the Atlantic Ocean by Long Beach Island, seawater enters the system through both Barnegat Inlet to the north and Little Egg Inlet to the south (NOAA, 1997) with freshwater inflow provided by coastal creeks. The eastern shoreline of Manahawkin Bay consists of bulkheads, marinas, docks and other shoreline infrastructure indicative to a developed, residential barrier island community, whereas the western shoreline is open and undeveloped salt marsh. On average, the Bay is between 2 to 3 km wide and 0.5 to 3 m deep at MLLW and supports monospecific beds of eelgrass (*Zostera marina*) and mixed beds of both eelgrass and widgeon grass (*Ruppia maritima*). The Intracoastal Waterway (ICW) is the primary channel utilized by vessels traversing the Bay and has a maintained depth of approximately 1.8 m (6 feet) within the project area.

MATERIALS AND METHODS

Identified recent SAV mapping surveys conducted within the Barnegat Bay-Little Egg estuary system (Kennish, M.J., 2001; McLain et al., 2001; Lathrop et al., 1999; McLain and McHale, 1997), in conjunction with other relevant SAV surveys performed in Chesapeake Bay and south Florida (Orth et al., 2001; Fourqurean et al., 2001), contributed to protocol development and the comparative analysis of survey results. ENSR SAV survey methodology was adopted and modified from NMFS recommended protocol outlined in *Seagrass Survey Guidelines for New Jersey* (Lockwood, 1991), NOAA protocol specified in *Guidance for Benthic Habitat Mapping: An Aerial Photographic Approach* (U.S. NOAA, CSC, 2001), and survey methodology used in the Virginia Institute of Marine Sciences (VIMS) *2000 Distribution of Submerged Aquatic Vegetation in the Chesapeake Bay and Coastal Bays* (Orth et al., 2001).

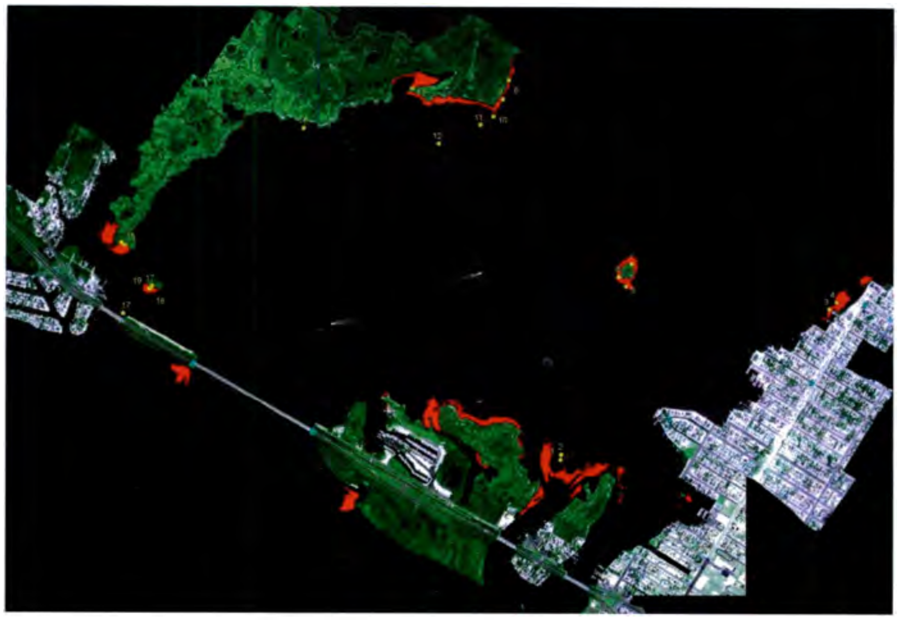

Fig. 2. Survey result and identified HAPC.

The aerial hyperspectral survey was performed by Spectrum Mapping LLC. (Spectrum) on July 5, 2002, using an AISA (Airborne Imaging Spectrometer for Applications) airborne hyperspectral imaging sensor consisting of the following basic components: compact hyperspectral sensor head, miniature GPS/INS sensor, data acquisition unit, and CaliGeo post-processing software. The hyperspectral sensor was mounted in a standard photogrammetrical camera port located within the fuselage of a twin engine, Piper Navajo aircraft. Data collection and hyperspectral imagery were performed from an altitude of approximately 3,300 feet above ground level yielding imagery at 1-meter pixel resolution. Ten (10) overlapping flight lines, covering approximately 3.75 square miles (9.7 square km) of estuarine habitat within Manahawkin Bay, were flown in an east/west direction. The selection of flight lines was predetermined by Spectrum and ENSR and included those areas within or adjacent to the proposed project area with water depths less than three (3) meters at mean low water and areas previously mapped or identified as SAV habitat (McLain et al., 2001; Bologna et al., 2000; Lathrop et al., 1999; McLain and McHale, 1997). Eighteen (18) control points were obtained from various fixed land features prior to flight with the use of a handheld Trimble GPS unit. In addition to the eighteen control points, the Barnegat Light USCG station was contacted to determine exact position of two fixed Intracoastal Waterway (ICW) markers located within Manahawkin Bay. All points were utilized in the final mapping process to provide data accuracy and precise SAV location.

On July 23, 2002, an SAV groundtruthing survey was conducted at 20 predetermined locations within Manahawkin Bay to verify hyperspectral results (Fig. 2). Individual survey stations were accessed via a shallow draft, 14-foot aluminum jonboat outfitted with a 25 hp, hand tiller outboard. Latitudinal and longitudinal coordinates used to locate and identify each station were converted into Universal Transverse Mercator (UTM) 18, Nad 83, and uploaded to a handheld Trimble GPS unit prior to survey commencement. Upon station arrival, a weighted buoy was deployed above the site coordinates to mark station location and ensure position accuracy. Ground confirmation of SAV presence/absence, relative abundance and distribution, percent coverage per quadrat, blade length (when applicable), random stem counts, and vegetative color of SAV beds were determined using snorkel and quadrat sampling. Percent coverage of individual species per meter within each survey station was determined by visually comparing each quadrat in relation to the crown density scale developed for estimating crown cover of forest trees from aerial photography (Orth et al., 2001; Paine, 1981). Random stem counts consisted of counting the "live stems" within three grids of each quadrat and recording general characteristics of vegetative health. Water quality parameters were measured with a Hydrolab Surveyor 4 Multipurpose Water Quality data logger and sonde at each survey site. USGS real-time water level data was downloaded from USGS tide gage 01409146 located within East Thorofare, Manahawkin Bay near Ship Bottom, New Jersey for July 23, 2002. The gage provided real time water level data every 6 minutes throughout the duration of the survey. Water level relative to Mean Sea Level (MSL) at each station was calculated by taking the depth of water from substrate and adding or subtracting the tide data based on the proximity of the tide cycle and time of sampling. Detailed results can be obtained by contacting Capt. Al Modjeski, ENSR

Corporation, at 20 New England Avenue, Piscataway, New Jersey or via e-mail at amodjeski@ensr.com.

RESULTS

Collected aerial data consisted of 16 spectral channels with an average bandwidth of 5 nanometers (nm) ranging from 450 to 840 nm. Spatial resolution was 1 meter in the cross track measurement. The flight lines were mosaiced together to create a single image. This mosaic was then classified to identify the terrestrial portions of the area to be removed from further analysis. Once subset from the imagery, the sub-aquatic regions of the imagery were visually assessed to identify areas of variance and possible SAV and/or bottom substrate differences. These locations were identified in the imagery and a first-order polynomial algorithm was used to improve the positional accuracy to +/−2 meters. Collected aerial data, in conjunction with ENSR ground survey data, was carefully analyzed, interpreted, and mapped by Spectrum Mapping LLC to give precise location of SAV beds within the study site. The final image created was a geo-referenced file navigated with an airborne Inertial Navigation System (INS) corrected with satellite airborne differential GPS (DGPS). The image was also radiometrically calibrated to allow for other spectral data source comparisons, and mosaiced into a single balanced image (Fig. 2). SAV location of varying densities is depicted in red, estuarine areas void of SAV are in black, vegetated landmasses are in green, and populated regions are in gray. The total calculated area of all identified SAV and subsequent HAPC for summer flounder within the flight coverage area was 109,083 square meters (26.955 acres). Vegetated SAV habitat was patchy and identified at 12 of the 20 stations surveyed which includes stations 1–8, 12, 15, 16, and 18. In addition, three (3) new beds were identified that had not been mapped in prior surveys. No SAV/HAPC was identified within the proposed ROW (Fig. 2). An additional Braun-Blanquet survey performed mid-August and early September, 2002 by Crofton Diving, further confirmed the absence of vegetated SAV habitat within the ROW. A boat-based bathymetric survey of the proposed cable crossing conducted in July also concurred with the hyperspectral determination of an SAV distribution depth limit of 1.31 meters at mean sea level (MSL). Overall, the proposed ROW would not impact SAV habitat or HAPC for summer flounder since habitat was absent adjacent and within the proposed ROW.

DISCUSSION

As previously stated, there was approximately 26.955 acres of HAPC for summer flounder within the Manahawkin Bay survey site in 2002. No SAV/HAPC was identified within the proposed ROW and therefore SAV/HAPC would not be affected by the proposed ROW. Even though the survey was conducted during a period of normal seasonal dieback, the utilization of aerial hyperspectral imaging in conjunction with groundtruthing allowed for similar or more accurate determination of SAV/HAPC location and acreage than conventional aerial and boat-based methodology conducted in periods of visual SAV abundance. This near real-time technology, in turn, allowed for a quicker, more definitive approach in determining the environmental feasibility for project locations by pinpointing SAV/HAPC habitats during pre-planning stages and allowing for location determinations that would avoid and minimize impacts to that habitat. Prior SAV surveys performed in Manahawkin Bay from 1986 through 2001 did not identify three (3) SAV beds located along the northwestern shoreline of the Bay. However, these beds were identified with hyperspectral imaging technology (1-meter resolution) combined with ground verification. It is possible these beds were recently established, relocated, or nonexistent during past surveys. It is also possible that the area was overlooked based on individual aerial interpretation and transect location. Because hyperspectral data does not require photo-interpretation but relies on scientific groundtruthing and identified hyperspectral signatures applied to larger tracts of habitat, accurate results are both qualitative and quantitative and can be used in future monitoring studies to determine yearly habitat variation over a larger area.

The majority of previously mapped SAV within the project area historically existed along the eastern shoreline of the Bay in shallow, protected areas or along the margins of small bay islands (McLain et al., 2001; Bologna et al., 2000; Lathrop et al., 1999; McLain and McHale, 1997). Some of these areas are now not vegetated, which could stem from a myriad of physical and chemical variables associated with dynamics of a shallow water estuary and a variety of anthropogenic sources. Increased population growth along the eastern shore of the Bay involves encroachment of habitat, over-utilization of habitat, and habitat modification by dredging, dock construction, and waterfront development. Other factors associated with decline of SAV within the project area and the inability of SAV to utilize unvegetated habitat could include increased recreational boating, bed scarring of vegetated areas from propellers and jet skis, increased turbidity, wasting disease, algal blooms, and variable water quality (Kennish, 2001). Eastern bed location from the ENSR survey was similar to past surveys and showed an increase in unvegetated habitat and a general decline in SAV population. The survey also identified newly discovered SAV beds along the western shoreline, possibly indicating local bed movement, relocation, or establishment. The lack of SAV within the ROW is most likely a function of depth, bed movement, and species decline. Shoreline boundaries of the ROW are in close proximity to the western beds and the historical trends evident in the aforementioned surveys do show a general SAV decline in that region of the Bay.

Past survey methodologies and different mapping techniques make it difficult to quantify decline of SAV habitat and HAPC availability versus magnitude of bed movement within the project area. Regular quantitative monitoring through remote sensing techniques like hyperspectral imaging could determine the extent of movement and degree of decline of available SAV habitat or HAPC. This, in turn, could assist in determining direct and indirect adverse influences contributing to those changes and the area of habitat available for summer flounder HAPC. SAV distribution and location determined by the ENSR survey did confirm trends relative to results from annual studies conducted in the Barnegat Bay-Little-Egg Harbor estuarine system in 2001, 2000, 1999, and 1995–1996 (McLain et al., 2001; Bologna et al., 2000; Lathrop et al., 1999, McLain and McHale, 1997). Previous survey results, when analyzed in successive order, showed a steady decline, rather than movement, in SAV and summer flounder HAPC distribution within the Barnegat Bay-Little Egg estuary system and subsequently a similar decline of SAV habitat within Manahawkin Bay. Inadvertently, future decline in SAV or HAPC for summer flounder could adversely affect the future recruitment of local summer flounder stocks due to continued loss of natural cover and related forage species associated with SAV. Periodic hyperspectral surveys could be used to quantify, compare, and confirm SAV population trends and accurately identify decreasing trends and HAPC availability. In addition, suitability of unvegetated habitat could be quantified and identified for potential SAV re-establishment based on by substrate type, depth, and proximity to other limiting factors.

REFERENCES

Bologna, P., K. Able, R.G. Lathrop, and P.B. Bowers. 2000. *Assessment of the Health and Distribution of Submerged Aquatic Vegetation from Little Egg Harbor, New Jersey.* Technical Report #2000-11, Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ. 15 pp.

Fonseca, Mark, W. Judson Kenworthy, and Gordon Thayer. 1998. *Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters.* NOAA Coastal Ocean Office. Decision Analysis Series No. 12.

Fourqurean, J.W., A. Willsie, C.D. Rose, and L.M. Rutten, 2001. *Spatial and Temporal Pattern in Seagrass Community Composition and Productivity in South Florida.* Marine Biology 138: 341–354.

Kennish, M.J. Editor. 2001. *The Scientific Characterization of the Barnegat Bay – Little Egg Harbor Estuary and Watershed.* Technical Report – Barnegat Bay Estuary Program, Toms River Estuary, 1100 pp.

Lathrop, Richard G., Renee Styles, and Sybil Seitzinger. 1999. *Use of GIS Mapping and Modeling Approaches to Examine the Spatial Distribution of Zostera marina in Barnegat Bay, New Jersey.* CRSSA and the Institute of Marine & Coastal Science, Rutgers University, New Brunswick, NJ.

Lockwood, Jeffrey. 1991. *Seagrass Survey Guidelines for New Jersey.* Div. Of Habitat and Protected Res., National Marine Fisheries Services, Sandy Hook Laboratory, Highlands, New Jersey. 10 pp.

McLain, Paul and Melissa McHale. 1997. *Barnegat Bay Eelgrass Investigations 1995–1996.*

McLain, Paul, Brent Burke, and Scott M. Cadigan. 2001. *Submerged Aquatic Vegetation in OceanCounty Map.* Prepared by the Ocean County Department of Planning. October 2001. http://www.savebarnegatbay.org/egwg.html.

Mid-Atlantic Fishery Management Council. 1998. Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan. National Oceanic and Atmospheric Administration. October 1998.

National Oceanic and Atmospheric Administration (NOAA). 1997. Nautical Chart 12324 *Intracoastal Waterway. New Jersey: Sandy Hook to Little Egg Harbor.* 28th ed.

Orth, R.J., D.J. Wilcox, L.S. Nagey, J.R. Whiting, and J.R. Fishman. 2001. *2000 Distribution of Submerged Aquatic Vegetation in the Chesapeake Bay and Coastal Bays.* VIMS Special Scientific Report Number 142. Final report to U.S. EPA, Chesapeake Bay Program, Annapolis, MD. Grant No. CB993777-02-0, http://www.vims.edu/bio/sav/sav00.

Paine, David P. 1981. *Aerial Photography and Image Interpretation for Resource Management.* John Wiley & Sons, Inc., New York City, NY. 571 pp.

U.S. NOAA Coastal Services Center. 2001. *Guidance for Benthic Habitat Mapping: An Aerial Photographic Approach* by Finkbeiner, Mark [and by] Bill Stevenson and Renee Seaman. Technology Planning and Management Corporation, Charleston, SC. (NOAA/CSC/20117-PUB).

BIOGRAPHICAL SKETCH

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Aleksandr "Capt. Al" Modjeski is a USCG licensed boat Captain and Senior Marine Ecologist with ENSR Corporation. With over 11 years experience, he has developed, conducted, and supervised numerous water quality and benthic assessments, authored Environmental Assessments and Impact Analyses associated with submerged cables and proposed pipeline corridors, performed myriad Essential Fish Habitat (EFH) assessments; conducted an ESA Section 7 for the Northern right whale in the Gulf of Maine; assisted with coastal and tidal wetland mitigation/restoration projects; conducted, coordinated, and developed protocol for T&E surveys from project inception to conclusion; mapped SAV habitat with the use of aerial hyperspectral imagery, and has built and designed an artificial reef in Puerto Rico. Past work experience includes duties at the Forsythe National Refuge in Brigantine, New Jersey; commercial fishing in the Gulfstream offshore South Carolina, various research for the New Jersey Department of Environmental Protection Bureau of Marine Fisheries, and scientific research in South Carolina, the Gulf of Mexico, and Costa Rica. Representative species surveyed include bald eagles, barred owls, various shorebirds, Pine Barrens tree frogs, pine snakes, bog turtles, swamp pink, leatherback sea turtles, striped bass, winter flounder, tautog, black sea bass, Japanese crabs, blue crabs, fiddler crabs, and a number of other marine and terrestrial threatened and endangered plant and animal species. In addition, he remains an active, appointed board member to the Bradley Beach, New Jersey Environmental Commission, Shark River Cleanup Coalition, and the New Jersey Corporate Wetlands Restoration Partnership. He recently supervised/organized horseshoe crab surveys and egg counts with candidate Eagle scouts within Shark River NJ and initiated coastal lake water quality surveys with local elementary school students. He also assists with data collection for the National Marine Debris Monitoring Program and acts as an environmental liaison between the environmental commission and the local fishing club. Capt. Al was also the 2003 Central New Jersey Eastern Surfing Association Season Champion for Master's Longboarding.

Part XII
Public Participation

Public Perception of Powerline Right-of-way Management: A Review of Current Knowledge

Brian N. Clark, J. Mark Fly, David A. Buehler, and Richard M. Evans

We completed nine focus groups on perceptions of powerline right-of-way (ROW) management issues. In these groups we interviewed eastern Tennessee residents to determine the nature and range of knowledge and views regarding vegetation management, ROWs as wildlife habitat, and ROW aesthetics. We also conducted an extensive literature review to adduce other pertinent data. Participants in focus groups exhibited a wide range of attitudes and beliefs about the interview topics. Some associated wildlife habitat with areas devoid of humans ("wilderness" or "sanctuary"), whereas others thought of habitat as close as "my backyard." A majority referred to habitat in relatively objective terms such as "food, water, and cover" or "homes for wildlife" or gave examples of habitat types. Most participants preferred brush cutting to herbicide use for ROW vegetation management, but several recommended establishment of low-maintenance cover on ROWs or cooperation between landowners and utilities to improve existing ROW programs. Many were skeptical that habitat could be managed by humans to benefit wildlife, though most approved of selective herbicide use if it were proven to enhance habitat. Most participants favored grass cover over shrubs or saplings on ROW for aesthetic or utilitarian reasons. Except for our pilot study, we found no other published research directly addressing public perceptions of ROW management. However, forestry aesthetics research has identified some trends in preferences among landscape and vegetation types that are useful to ROW managers and planners; we present such relevant data in this paper along with our study's results.

Keywords: Aesthetics, focus groups, herbicides, public perceptions, right-of-way management, wildlife habitat, right-of-way

INTRODUCTION

Because electric transmission line rights-of-way (ROWs) traverse millions of hectares of private and public lands, and their care touches upon myriad environmental and social issues, public perception is an important concern for ROW and land managers (Rich et al., 1994; Norris, 1997; Bell, 2000; Vierima and Goodrich-Mahoney, 2000). We initiated a preliminary study of public perceptions of powerline corridor management in 1993 and found little related research (Clark et al., 1993). In that study we analyzed ROW management program complaint records from a large, public electric utility in the southeastern United States and conducted a pilot-test focus group with a conservation group to discuss ROW issues of potential importance to the public at large.

Based on this preliminary research, we began a more thorough study on perceptions of ROW management, which entailed eight additional focus groups. The purpose of this study was to identify the nature and range of: (1) perceptions of right-of-way vegetation treatments; (2) perceptions of ROWs as wildlife habitat; and (3) aesthetic preferences among basic ROW vegetation types. We also conducted an extensive review of current literature to determine whether related studies had been completed and to shed light on this topic using other relevant research.

METHODS

Interviews

We used focus group interviews (Krueger, 1988; Clark et al., 1994) with landowners and members of other tar-

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geted publics in three eastern Tennessee counties. We identified three target publics from which to recruit participants: (1) adults ($\geq$ 18 years of age) who were present or past owners/renters of property with electric transmission line crossings; (2) adults who have never resided on property with transmission easements (the "general public"); and (3) natural resource interest groups. Each focus group was composed of either members of the same public with the same residential status (urban, suburban, or rural/farming for profit), or members of an interest group (Wells, 1974; Krueger, 1988). We recruited participants for two pilot-test focus groups from meetings of three civic organizations.

For the two pilot-test groups we offered a gift to civic organization members as an incentive for participation and screened out landowners with transmission line easements on their properties. For the remainder of groups we offered a monetary incentive for participation and screened out electric utility employees, close friends and close relatives of electric utility employees, and employees of the University of Tennessee.

Study area

Most focus group participants were residents of Knox County, which occupied 1,317 km^2 of eastern Tennessee land area and had a total population of about 336,000 (U.S. Bureau of Census, 1992). Knox County is home to metropolitan Knoxville, in which about 50% of the county's residents lived. Most residences in the county were urban (78%) and non-farm rural (21.7%); farm residences totaled only 0.3% (U.S. Bureau of Census, 1992). Knox County was composed primarily of whites (89%) and African Americans (9%); Asians, Native Americans, and other races totaled about 1% of the population (U.S. Bureau of Census, 1992). Per capita income in 1992 was $17,382 (Tennessee Industrial Development Division, 1994). Persons with high school diplomas or fewer years of formal schooling constituted a slight majority (53%) of the resident population >25 years of age, while 41% reported having at least come college (U.S. Bureau of Census, 1992). The county's major industries include agriculture, textiles, manufacturing, electronics, and communications (Tennessee Industrial Development Division, 1994). The county is within close commuting distance to the Cherokee National Forest and Great Smoky Mountains National Park to the south and east, and several surrounding state forests, wildlife management areas, natural areas, and scenic rivers.

Participants also resided in Blount and Monroe counties. Blount and Monroe counties had populations of approximately 86,000 and 30,500, respectively, and each had a slightly larger land base than Knox County – 1,447 and 1,645 km^2, respectively (U.S. Bureau of Census, 1992). Residents of these counties were more apt to reside in suburban or rural settings, and the median income and years of formal education were less for these counties, than those of Knox County (U.S. Bureau of Census, 1992).

Data analysis

We compiled data from the first pilot-test focus group with the other eight groups. We then coded and analyzed responses using HyperRESEARCH computer software (Version 3.0, ResearchWare, Randolph, Massachusetts, 1994). We sorted comments by topic and response type, compiled lists of responses to each question, and identified representative or poignant quotations. We then tallied response types and identified the range of responses to questions as well as recurring or unusual themes or ideas (Krueger, 1988).

Literature review

We used several scientific referencing databases and Internet search engines to search extant literature for research on ROW management. Upon finding no other empirical studies relating directly to perceptions, we broadened our search to include papers on tangent topics, including public perceptions of forestry aesthetics, vegetation management, and wildlife habitat management.

RESULTS

Focus groups

Participants

A total of 51 people participated in nine focus groups. Of the 1,054 households we telephoned to recruit participants, 13% met screening criteria and agreed to participate and 37% of those recruited actually participated. Fewer recruiting calls were required for the last three groups, and percent attending based on telephone committal was also greater than for the previous groups, presumably because we doubled the monetary incentive for participation.

A majority of interview participants resided in Knoxville ($n = 22$) or Knox County ($n = 19$). Blount County was represented by nine participants, eight of whom took part in the final group. For analytical purposes, we considered suburban/rural residents as those who lived outside of metropolitan Knoxville. Twice as many males attended discussions as did females, although only slightly more males were recruited for groups. Racial distribution among participants was predominately Caucasian (90%), with one person from each of Asian, Native American, Native American-Caucasian, African-American, and Hispanic descents participating. Ages were well distributed.

Educational attainment levels ranged from elementary school to graduate degrees, though most participants who reported their educational background had one or more years of college (73.9%). Focus group participants had notably higher educational attainments, on average, than the populations of Knox, Blount and Monroe counties, as nearly 60% had at least a four-year degree.

Annual incomes were fairly well distributed among categories offered on the demographic questionnaire.

The income categories most frequently indicated were \$20,000–\$29,999 (19%), \$30,000–\$39,999 (19%), and \$50,000–\$59,999 (14.3%). As with educational attainment, income was skewed high in our sample relative to the population sampled, though nine participants did not report their incomes. Most (85%) did not farm for profit.

Perceptions of vegetation treatments

When asked about familiar methods used to maintain or manage ROWs, the vast majority of participants with transmission ROWs crossing or adjacent to their property identified mechanical or manual cutting. Those responding in "general public" or civic groups frequently knew about or guessed common methods of ROW management, including cutting with brush-hogs or chainsaws (27/40), or herbiciding (13/40). Among landowner and general public participants that believed herbicides were being used to treat ROW vegetation in some areas, few were certain; most had either heard of herbicide use on ROWs ("I've heard of them spraying but I never have seen them spray") or had seen evidence of their use (e.g., saplings under or trees adjacent to ROWs defoliated) and had drawn their own conclusions. One landowner remarked, "they do a lot of spraying around the powerlines; they spray those [ROWs] that are on our property at times, and I assume [they do it] with a helicopter." Another surmised, "I don't know what else could be killing off the trees that grew up near those lines or around them."

Many landowners that had transmission lines crossing their property were satisfied with past brush cutting and the relationship they had with the responsible utility. However, several wanted a more regular treatment cycle so that cut brush would not create an eyesore on ROWs. "If they'd cut it regularly like they should, every three years or so, they could chop it up like grass, but this knocking it [large brush] down and leaving it laying is bad," one landowner stated. A few group participants angrily referred to brush-hogging large sapling stems as "mangling" trees and "raping" the land, and that such was "definitely *not management*." These landowners felt strongly that a relatively short (~three-year) brush-cutting cycle was the most economical, safe, and aesthetically pleasing means of ROW management.

Responses to the question, "How would you feel about herbicides being used to treat the vegetation on rights-of-way?" were varied. However, the overriding concern expressed by ROW-landowners on their property was for landowner-utility contact prior to herbicide use. Landowners felt this would enable them to voice concerns and ask questions about chemicals being proposed for use, and it would allow them to take actions (if necessary) to protect their interests, such as temporarily moving livestock out of an area scheduled for treatment. Some landowners and members of other publics were adamantly against ROW management with herbicides. A few landowners said they would manage the vegetation themselves if confronted with herbicide use on ROWs as their only alternative.

Many ROW-landowners said they would allow or consider herbicide use on ROWs depending on the proximity of treatment to homes and water sources, the characteristics of the herbicide being used, the application method, and the types of land-use activities on and around ROWs. Some landowners were specific about their criteria for herbicide use on ROWs; these could be summarized as "controlled" and "careful" applications that are "safe" in terms of human and environmental health, and validated by "long-term" research. Few landowners were unconditionally supportive of ROW management with herbicides.

Some general public participants regarded herbicide application as more acceptable in "steep" or "rough" terrain conditions that preclude alternatives. The combination of remoteness from people and residences, and difficulty in accessing ROWs for brush cutting in such conditions seemed to make herbicides a more acceptable option to them.

Participants most frequently mentioned health and environmental risks as potential drawbacks of herbicide use on ROWs. They identified cost savings, ease of application, and effectiveness as the greatest prospective benefits of herbicidal treatments.

Wildlife habitat and ROWs

When participants were asked to associate the first word or phrase that came to their minds upon hearing "wildlife habitat," responses ranged from specific habitat components such as "cover" to value-laden sentiments like "nature at its best." The most prevalent response types were: definitive (18/69), exemplary (13/69), or exclusive (13/69). "Food, water, and cover," and "home for wildlife," were typical definitive responses in which a definition or specific habitat component was given. Two participants specifically stated that habitat was "varied," because wildlife may be "transitional and migratory." Exclusive responses, or those indicating a perception of habitat as devoid of human intervention, were those given by participants who associated habitat with "protection" or "seclusion." "Natural," "undeveloped," "not planned or landscaped," "unimproved," and "away from cities – a place set aside" were other exclusive responses. The concept of "sanctuary" seemed representative of exclusive responses; one participant even mentioned enclosures or "fences" as a part of their conception of wildlife habitat.

"National park," an exclusive response, was also identified as the first thing that came to mind when some participants thought of "wildlife habitat." On the other hand, one participant responded to another's association of "no people" with wildlife habitat by saying: "You *can* have wildlife in places where people are; that was really obvious to me recently when I went to Yellowstone National Park. The buffalo, the elk, the deer, the mule deer and everything else [were] roaming around out there and the place [was] full of people." Another shared that she "used to think that you had to have ... trees" for habitat, but after observing Yellowstone's open areas and burned-over habitat that were productive for wildlife, she recognized that habitat was not monolithic.

Exemplary responses were fairly common in habitat free associations. These entailed a sample habitat or cover type being identified. Examples of habitat ranged from systems such as "the prairies of Yellowstone" to seemingly simpler habitat components such as "caves." "Jungle," "forest," "trees," and "brush" were each mentioned more than once. Nearly one-fifth of participants (10/51) expressed a lack of familiarity with the term "wildlife habitat" or declined to respond. "I don't know that I've heard it, but I just assumed it was wild animals' home," one such person said. Sentimental response types (i.e., "nature at its best" or "free spirits") were observed least often (2/69).

Most responses (33/51) to the question, "Have you ever thought of a right-of-way as wildlife habitat?" were negative, either because they had "really never thought about a powerline [corridor in] that way" or because they thought of ROWs as "cleaned out" and thus lacking habitat value. Several participants indicated they perceived ROWs to be "exactly the opposite" of habitat because they were periodically cleared; they believed "animals don't like" areas like ROWs that seem "unprotected and barren." Conversely, members of the hunting club and participants from other groups who were hunters or had personally seen wildlife in ROWs asserted that the utility corridors were used by wildlife, or that they *could be* developed for habitat. One hunting club member said, "All powerline right-of-ways are usable for wildlife habitat." Hunting-club members advocated the cultivation of "food plots" for enhancing ROW habitat. An environmental organization member reflected upon her experience, "I've seen some wild turkeys and deer out in the cleared part, and as long as they've got the forest on each side, they might do some grazing out there [in the ROW]." One hunter viewed powerline corridors as "one of the best places in the world to rabbit hunt around because there is scrub growth," further noting that he believed that scrub-shrub cover is decreasingly available in eastern Tennessee. A rural farmer commented, "It's good quail habitat, at certain stages, but then when they come through and whack it [the vegetation] all down, then they've destroyed it all and it takes a year or two before the rabbits and the quail and everything else will start back [using the ROW]." A city resident pointed out that the management of ROWs would "encourage some [wildlife species] and discourage others," but like several other participants, he seemed to be averse to the practice of *managing* wildlife: "In terms of wildlife, it is no longer *wild* life – we've made an intervention – it has become *managed*."

Participants shared diverse sentiments when questioned about habitat management. Few were familiar with the concept, and to many the idea of manipulating vegetation to benefit wildlife was foreign or viewed aversely; one said, "I think there are a lot of parks – places that are nice to visit and see wildlife ... that are not in their natural state; I can think of a lot of places where things have been [managed]," but she later said that this was not desirable. However, a majority of those responding (24/37) *were* open to the idea of habitat management with herbicides *conditionally* – "if it could be shown to *really* benefit the wildlife." Seven participants completely rejected the proposition that habitat could be managed with herbicides. A few who responded were "unsure about it" or didn't "have enough knowledge to have an opinion."

Aesthetics of ROW vegetation

When asked to view photographic slides and rank three vegetative cover types beneath transmission lines in terms of personal preference, participants preferred grass cover or shrub-scrub cover over tall brush. Irrespective of demographics, responding participants overwhelmingly (26/36) ranked the grass cover highest, describing it as "neater" or "more productive" than other vegetation types. "Soccer fields," walking trails, or "pastures," in addition to utilities' access to lines and structures were among the "productive" uses enumerated for grassy ROWs. Participants most often ranked the low scrub-shrub cover second, citing wildlife cover value and visual appeal as their main motivations. A few identified the contrast between grassy ROW cover and surrounding forest as a "scar" on the landscape; they stated that tall brush would not create such a stark contrast, and that it would serve to screen electric facilities or "distract [a viewer's attention] from a powerline." One person believed that tall sapling cover would be "least expensive to maintain." Another said that the brush cover was "more natural." On the other hand, participants who disliked tall brush cover on ROWs attributed their feelings principally to the lack of uses (including access) available on land with such cover and to its "unkept" appearance. Some even stated that it was "dangerous" because of its proximity to the lines.

Literature review

We found no references to empirical studies directly addressing public perceptions of ROW management, excluding our previous work. However, we identified several research efforts that were related in some fashion and germane to our study. We provide below a brief summary of these data.

Regarding aesthetics of vegetative cover, participants in forestry studies preferred relatively mature, park-like forests with low to moderate stem densities and grass-forb understory cover (Buhyoff et al., 1979; Patey and Evans, 1979; Vodak et al., 1985; Hull and Buhyoff, 1986; Ribe, 1989; Brunson and Shelby, 1992; Johnson et al., 1994; Hands and Brown, 2002). Respondents rated natural scenes with predominant greenery or variations in color as aesthetically pleasing. Conversely, they disliked scenes with clearcut or dead vegetation, bare ground, and simple color schemes (other than green). Gobster (2001:477) summarized forest aesthetics research by saying preferences generally follow "a typical logarithmic growth curve, rising quickly in the first two decades after cutting, then increasing at a slower rate as stands begin to look more like mature forests." Few data were available on aesthetics preferences among grasslands and other early successional communities (Gobster, 1999), although limited research shows that savannahs or forests were preferred over wide, open grasslands (Raffetto, 1993; Ryan, 2000).

With respect to vegetation management, limited relevant data were available. These dealt primarily with clearcutting (somewhat analogous to mowing woody ROW vegetation, one of the most common ROW treatments). Clearcutting and other practices that revert wooded areas to earlier seral stages were typically viewed negatively (Vodak et al., 1985; McCool et al., 1986; Bliss 2000). Selective forest thinning is a more publicly acceptable practice, provided it yields definite benefits (aesthetic or otherwise) and people know why it is being done (Buhyoff et al., 1979; McCool et al., 1986; Vodak et al., 1988). We found no studies comparing perceptions of herbicides to other treatments, although treatments that result in brown-down or defoliation, or present a comparably higher risk to human or environmental safety, are generally disliked (Buhyoff et al., 1979; Slovic, 1990; Vaughan, 1990; Bliss, 2000; Hands and Brown, 2002).

While no other studies have addressed perceptions of wildlife habitat management in reference to ROWs, some have investigated the topic generally or in other contexts (see Kellert, 1980 and Responsive Management, 1997). For example, in a survey involving major metropolitan areas, a majority of respondents favorably reported actively trying to manage for wildlife around their homes or neighborhoods (Conover, 1997). Hands and Brown (2002) found that those surveyed preferred ecological rehabilitation scenes that had been modified by addition of bird nesting structures. Public knowledge improved attitudes toward management practices, even those that were perceived as inherently risky (Taylor and Daniel, 1984; Ribe, 1999). Perceptions of management practices were more favorable if seen as benefiting wildlife, although public knowledge of basic principles of wildlife management was very limited (Kellert, 1980; Alexander, 1987; Hastings, 1987).

DISCUSSION

Our focus groups elucidated a wide range of and some trends in perceptions of important issues to ROW and wildlife habitat managers. With respect to ROW vegetation, most participants viewed brush-cutting on short rotations positively, but looked unfavorably upon non-selective or broadcast herbicide treatments. This corroborates findings from other aesthetics research, presumably because short mowing rotations were perceived as producing more green herbaceous vegetation with less slash and brown-down, and simultaneously costing less to maintain. The possibility of large-scale herbicide application triggered participants' fears of unknown health and environmental risks; some viewed "spot spraying" and "selective" herbicide application as the only "proper use" of herbicides. A majority in our study preferred the "neat," "pastoral" qualities of grass cover (with low shrub cover preferred second most often) instead of tall brush cover on ROWs. Dense, young trees and shrubs were also perceived as unkempt in forestry studies (Patey and Evans, 1979; Hull and Buhyoff, 1986; Ribe, 1989; Priestley, 1992). This utilitarian perspective was consistent across demographic divisions. A few of our groups' participants ranked tall vegetation highest for its screening value or because of the lack of contrast with surrounding forestlands, as Priestley (1992:35) also found, or because of perceived habitat value. Interestingly, there were no differences in patterns of responses toward herbicides or vegetation types between landowners with ROWs on their properties and members from other publics, mirroring the trends observed elsewhere in forestry and aesthetics research.

Direct, personal experience with wildlife appeared to be a crucial factor affecting participants' views of habitat and its management, both in ROWs and otherwise. A birdwatcher, for example, felt strongly that management favoring shrubby vegetation on ROWs could benefit songbirds and eastern cottontails – she had seen them using a regenerating, cutover ROW adjacent to her property. The proximity of our study area to Great Smoky Mountains National Park and participants' familiarity with the Park's highly visible wildlife was evident in several other responses. One man associated "dens or holes" with habitat because he "automatically thought of the Smoky Mountains" and the bears there. Two participants in different groups mentioned that their perceptions of habitat had been influenced by visits to Yellowstone National Park. Women (8/17) were unfamiliar with or offered no association with the term "wildlife habitat" more frequently than men (2/34); interestingly, seven of these women resided in rural areas. Men (17/34) were about four times as likely to consider ROWs as wildlife habitat than women (4/17). Several males referenced game species or hunting when discussing habitat, reinforcing the importance of experience in perceptions of habitat (see Mankin et al., 1999).

Although researchers (e.g., Kellert, 1980 and Mankin et al., 1999) have found widespread public concern about wildlife and habitats, our results confirm an observed lack of public awareness of *management that benefits wildlife*, from as close as New England (Alexander, 1987) and even eastern Tennessee (Hastings, 1987). Programs designed to enhance habitat, particularly those that will interface the public, should include the dissemination of cogent but basic information. Land managers have a two-fold task of specifically demonstrating the usefulness of ROWs for wildlife of concern and articulating how ROW management will impact their habitats (Clark, 1995).

Our sample was skewed toward higher formal education and income compared to the broader eastern Tennessee population, and the vast majority of participants were white males. The higher attrition among recruited females may have been because of the announced general topic (Krueger, 1988) of the focus group discussions – "powerlines." Similar studies in the future may require different recruitment strategies for women (or perhaps higher monetary incentives for participation), without biasing recruitment to include only "interested publics." The predominance of males in our groups may have biased our results, but frequencies of response types except for free associations with habitat were answered similarly between the sexes. Although we doubled the participation incentive during our study, we did not detect biases in participants' demographics as a result; only participation was affected.

The formal education levels and relative affluence of many participants may explain why there was ubiquitous apprehension about herbicide use. The few farmers (7/51) that participated were more familiar with specific herbicide trade names, effects, and benefits, and they were less likely to be adamantly against herbicides based on their personal experience with pesticide use and more utilitarian perspectives on land use.

Although our study should not be construed as a representative survey of an entire population, our data do suggest trends and provide a range of perceptions that utilities and wildlife managers should consider or further investigate in their service areas. First, our findings highlight the need for managers to focus on information and education needs of constituents regarding the potential values of ROWs to wildlife, the importance of habitat management, and the benefits of certain herbicide treatments. For example, women living in rural areas in eastern Tennessee appear to be unfamiliar with popular wildlife terminology and probably need more information about beneficial ROW or wildlife management programs than most urbanites or men. Second, the contingent nature of participants' views (independent of demographics) toward herbicidal management of habitat shows that managers must convincingly demonstrate how herbicides are advantageous if they are to garner public support for them. This is important because wildlife managers extensively use herbicides to improve habitats ranging from grasslands (e.g., Washburn et al., 2000) to forests (e.g., Conner et al., 1981), many of these improvements are user or taxpayer funded, and some require public review. Third, the overwhelming preference of focus group participants for grass cover on ROWs indicates that programs that promote stable grassland communities may be widely popular. This presents a potential challenge in terms of public perceptions for managers promoting scrub-shrub communities on ROWs or other open lands.

Additional perceptions research is needed on aesthetics of grasslands in general (Gobster, 2001) and ROW vegetation in particular, as well as on the impact of information and education efforts on perceptions of habitat management. However, our findings support the proposition that ROWs present an essentially untapped opportunity for cooperative management between landowners, utilities and others to partner in establishing more appealing vegetative cover, enhancing wildlife habitat, and obtaining other benefits in a concerted manner (see: Brown, 1993; Clark, 1995).

REFERENCES

Alexander, L. 1987. Nonindustrial private forest landowner relations to wildlife in New England. Ph.D. Thesis, Yale University, New Haven, Connecticut. 228 pp.

Bell, S. 2000. Can a fresh look at the psychology of perception and philosophy of aesthetics help contribute to the better management of forested landscapes? Pages 125–148 in S.R.J. Sheppard and H. Harshaw, editors. Forests and Landscapes: linking ecology, sustainability, and aesthetics. CABI, Wallingford, Oxon, United Kingdom.

Bliss, J.C. 2000. Public perceptions of clearcutting. Journal of Forestry, 98(12): 4–9.

Brown, D.T. 1993. Cooperative management of utility corridors in Canada. Proceedings of the International Symposium on Environmental Concerns in Rights-of-way Management, 5: 343–350.

Brunson, M.W. and B. Shelby. 1992. Assessing recreational and scenic quality: How does New Forestry rate? Journal of Forestry, 90(7): 37–41.

Buhyoff, G.J., W.A. Leuschner, and J.D. Wellman. 1979. Aesthetic impacts of southern pine beetle damage. Journal of Environmental Management, 8: 261–268.

Clark, B.N. 1995. Effects of tebuthiuron on wildlife habitat on two powerline rights-of-way and public perception of right-of-way management in eastern Tennessee. M.S. Thesis, University of Tennessee, Knoxville. 198 pp.

Clark, B.N., J.M. Fly, D.A. Buehler, and R.M. Evans. 1993. Public perception of powerline rights-of-way management. Proceedings of the International Symposium on Environmental Concerns in Rights-of-way Management, 5: 446–449.

Clark, B.N., J.M. Fly, D.A. Buehler, and R.M. Evans. 1994. Focus group interviewing for human dimensions of wildlife research. Proceedings of the Southeastern Association of Fish and Wildlife Agencies, 48: 604–611.

Conner, R.N., J.G. Dickson, and B.A. Locke. 1981. Herbicide-killed trees infected by fungi: potential cavity sites for woodpeckers. Wildlife Society Bulletin, 9: 308–310.

Conover, M.R. 1997. Wildlife management by metropolitan residents in the United States: practices, perceptions, costs, and values. Wildlife Society Bulletin, 25: 306–311.

Gobster, P.H. 1999. An ecological aesthetic for forest landscapes. Landscape Journal, 18: 54–64.

Gobster, P.H. 2001. Human dimensions of early successional landscapes in the eastern United States. Wildlife Society Bulletin, 29: 474–482.

Hands, D.E. and R.D. Brown. 2002. Enhancing visual preference of ecological rehabilitation sites. Landscape and Urban Planning, 58(1): 57–70.

Hastings, B.C. 1987. Wildlife-related perceptions of visitors to Cades Cove, Great Smoky Mountains National Park (Tennessee). M.S. Thesis, University of Tennessee, Knoxville. 278 pp.

Hull, R.B. and G.J. Buhyoff. 1986. The scenic beauty temporal distribution method: an attempt to make scenic beauty assessments compatible with forest planning efforts. Forest Science, 32: 271–286.

Johnson, R.L., M.W. Brunson, and T. Kimura. 1994. Using image-capture technology to assess scenic value at the urban/forest interface: A case study. Journal of Environmental Management, 40: 183–195.

Kellert, S.R. 1980. Public attitudes toward critical wildlife and natural habitat issues, U.S. Fish and Wildlife Service Technical Report 024-010-00-623-4. U.S. Government Printing Office, Washington, DC.

Krueger, R.A. 1988. Focus groups: a practical guide for applied research. Beverly Hills, CA: Sage Publications. 197 pp.

Mankin, P.C., R.E. Warner, and W.L. Anderson. 1999. Wildlife and the Illinois public: a benchmark study of attitudes and perceptions. Wildlife Society Bulletin, 27: 465–472.

McCool, S.F., R.E. Benson, and J.L. Ashor. 1986. How the public perceives the visual effects of timber harvesting: an evaluation of interest group preferences. Environmental Management, 10: 385–391.

Norris, L. 1997. Address environmental concerns with real data. Proceedings of the International Symposium on Environmental Concerns in Rights-of-way Management, 6: 213–218.

Patey, R.C. and R.M. Evans. 1979. Identification of scenically preferred forest landscapes. Pages 532–538 in G.H. Elsner and R.C. Smarden, editors. Our National Landscape: Proceedings of a National Conference on Applied Techniques for Analysis and Management of the Visual Resource, General Technical Report PSW-35: U.S. Forest Service, Washington, DC.

Priestley, T. 1992. Perceived impacts of electric transmission facilities. Edison Electric Institute, Washington, DC. 104 pp.

Raffetto, J. 1993. Perceptions of ecological restorations in urban parks. Pages 61–67 in P.H. Gobster, editor. Managing urban and high use recreation settings, General Technical Report NC-163. U.S. Forest Service, Saint Paul, Minnesota.

Responsive Management. 1997. The public and fish and wildlife management: a literature and research review. Responsive Management, Harrisonburg, Virginia. 405 pp.

Ribe, R.G. 1989. The aesthetics of forestry: what has empirical preference research taught us? Environmental Management, 13: 55–74.

Ribe, R.G. 1999. Regeneration harvests versus clearcuts: public views of the acceptability and aesthetics of Northwest Forest Plan harvests. Northwest Science, 73: 102–117.

Rich, A.C., D.S. Dobkin, and L.J. Niles. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on birds in southern New Jersey. Conservation Biology, 8: 1104–1121.

Ryan, R. 2000. A people-centered approach to designing and managing restoration projects: insights from understanding attachment to urban natural settings. Pages 209–244 in P.H. Gobster and R.B. Hull, editors. Restoring nature: perspectives from the social sciences and humanities. Island Press, Washington, DC.

Slovic, P. 1990. The legitimacy of public perceptions of risk. Journal of Pesticide Reform, 10(1): 13–15.

Taylor, J.G. and T.C. Daniel. 1984. Prescribed fire: public education and perception. Journal of Forestry, 82: 361–365.

Tennessee Industrial Development Division. 1994. Tennessee Community Data: Knoxville, Tennessee (brochure). Tennessee Department of Economic and Community Development, Nashville, Tennessee.

U.S. Bureau of Census. 1992. 1990. Census of population and housing, Summary Tape File 3-A. CD90-3A-53. U.S. Department of Commerce, Washington, DC.

Vaughan, E. 1990. Some factors influencing the nonexpert's perception and evaluation of environmental risks. Garland Publications, New York.

Vierima, T.L. and J.W. Goodrich-Mahoney. 2000. Right-of-way Communication Strategies. Proceedings of the International Symposium in Environmental Concerns in Rights-of-way Management, 7: 791–795.

Vodak, M.C., J.D. Wellman, and G.J. Buhyoff. 1988. Hardwood management and scenic preferences: study findings and how VFA members responded. Virginia Forests, 43(4): 10–13.

Vodak, M.C., P.L. Roberts, J.D. Wellman, and G.J. Buhyoff. 1985. Scenic impacts of eastern hardwood management. Forest Science, 31: 289–301.

Washburn, B.E., T.G. Barnes, and J.D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin, 28: 97–104.

Wells, W.D. 1974. Group interviewing. Pages 133–146 in R. Ferber, editor. Handbook of marketing research, Volume 2. McGraw Hill, New York.

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Barriers to Collaborative Nature Conservation Efforts in Rural Energy Corridors: A Case Study in Southern Québec

Darren R. Bardati and Cédric Bourgeois

The utility right-of-way (ROW) has been used as a green corridor, or "greenway," for beautifying the community, for enhancing recreational and educational opportunities, for wildlife habitat and biologically connecting ecosystem fragments. These forms of nature conservation have been considered as an effective method to expand utility profiles and improve public relations. At the same time, collaborative approaches to natural resource management, including ROW co-management, are being broadly promoted as promising ways to deal with complex and contentious public issues. This study examined the collaborative decision-making potential for a nature conservation corridor to be established in an existing multiple ROW that includes two natural gas pipelines and an electrical transmission line. In the rolling hills of rural southern Québec, where tourism-dependent communities and small, family-based farming and woodlot forestry operations prevail, the wide energy corridor fragments fields and forests, affecting land use, wildlife habitat, aesthetic value and quality of life. Nature conservation is advanced as a means to "add environmental value" to the perceived landscape scars. Based on document analysis and 45 in-depth personal interviews with landowners, utility company and government officials, the study found that fundamental barriers exist to effective collaboration for nature conservation despite initial willingness on the part of all to be involved in the project. These include lack of agreement of goals, inadequate communication, lack of trust, limited flexibility in "doing things differently," and barriers within the institutional framework.

Keywords: Public participation, collaborative decision-making, partnerships, nature conservation, multiple rights-of-way, Québec, right-of-way

INTRODUCTION

Everyone is familiar with scenes of angry local protestors hoping to block the development of new right-of-way (ROW) infrastructures in their backyards. These confrontations, often glamorized with much savor by the various media, do not help improve the ROW company's public image, nor are they particularly constructive in helping the protestors and company representatives to find solutions that are beneficial to both parties.

The need to establish proper communication strategies with communities affected by the presence of ROW corridors, the necessity of gaining public acceptance of new infrastructures, and the benefits of public-private cooperation in the siting of new ROWs have been discussed for years in professional publications and conferences, such as the Symposia on Environmental Concerns in Rights-of-Way Management. Likewise, much has been published about innovative management strategies to limit environmental damage in existing ROWs through, for example, sensitive vegetation management and protection of biological and cultural resources. What has received less attention is the potential for creating collaborative environmental partnerships between the utility company and the affected public for nature conservation. The challenge for any such partnership is to define and

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implement a place-appropriate vision of nature conservation through a process of collective understanding that seeks innovative solutions to conflicts and problems that serve multiple interests.

Research objective

The objective of this research was to explore the potential for the establishment of a nature reserve on a series of adjacent private properties along a multiple ROW corridor as a new form of collaborative environmental partnership.

Case study approach

To meet the research objective, a case study was chosen where there already existed a demonstrated desire to establish a nature reserve among a grassroots association of affected private landowners. In the rural municipality of South Stukely in southern Quebec, a 100-meter-wide corridor is shared by three different energy utilities and cuts across 34 adjacent private properties and extends 8.5 kilometers. The study area is adjacent to the Appalachian Corridor, a natural corridor in the extension of the Appalachian range north of Vermont (Fig. 1). Of particular note is that the desire to establish a nature reserve in this stretch of the countryside came six years after a "not in my backyard" confrontation between the affected private landowners and a pipeline company during the preparation and constructions phases of the third ROW. The parties involved faced a number of challenges in defining the vision for a nature reserve on private ROW lands, and there were significant barriers to the progress of their collaborative nature conservation efforts.

This paper reviews the literature on public participation in ROW management and discusses the findings of the South Stukely case study, including management implications and future research needs. The lessons learned through the South Stukely experience could serve to help utility companies and private landowners to improve collaborative environmental ROW planning efforts in other areas.

PUBLIC PARTICIPATION: FROM CONSULTATION TO COLLABORATION

In general terms, ROW planning and management require difficult public policy decisions concerning, for example, the extent to which natural resources are to be developed or preserved, where major facilities will be located, how they will be maintained, and what levels of risk are acceptable. Since most of these determinations are based not only on expert judgment but also on perceptions and values, effective planning and management decision-making require participation of interested parties. It has been long recognized that involving the public in ROW decisions that will be likely affect them is vital. In most jurisdictions across North America, some form of public participation in ROW planning and management is now mandated by law or government policy. Indeed, several studies have shown that identifying the public's perceptions of, and concerns about, ROW management is paramount to enhancing the utility company's image and establishing effective ROW programs (Clark et al., 1995; Brown, 1993; Vierima and Goodrich-Mahoney, 2002; Richards et al., 2002).

The nature of such participation has changed over the past 30 years. It was once characterized as *"tell us what you want, and we'll go away and decide what to do."* The most common techniques of participation have been public hearings and information sessions. Though they are sophisticated government mandated quasi-judicial devices for allowing the public access to the decision process, their critics have claimed that they tend to be adversarial in nature and do much to breed contempt and conflict between the utility company and affected communities. This approach also wrongly assumes that the public speaks with one voice. Planners often find themselves resolving conflicts among competing interests. Reaching decision means making trade-offs and achieving compromises which often leave competing interests dissatisfied. More recent advances in collaboration and public participation aim to go beyond traditional participation and conflict resolution. Collaborative approaches, characterized by *"tell us what you want and we'll all figure out what to do together,"* aim to involve the public in a process of collective understanding and learning that will contribute to innovative solutions that serve multiple interests (Randolph, 2004).

Collaborative planning is defined as a "collective process for resolving conflicts and advancing shared visions involving a set of diverse stakeholders" (Carr et al., 1998, 768). The stakeholders are the parties with a common interest in a particular issue and may include energy companies, government regulators, private landowners, environmental or other interest groups, and ordinary individuals. By identifying and developing common goals, stakeholders can create practical solutions through consensus (Wondolleck and Yaffee, 2000).

The four basic elements of collaborative environmental planning are presented in the following list:

- *Stakeholder's involvement*: Early and extensive engagement of stakeholders in the process of planning, decision making, and implementation. Stakeholders are those effecting change in the environment and those affected by it;
- *Scientific basis*: Strong and sound scientific information and analysis on which to base decisions;
- *Holistic, proactive approach*: Holistic understanding of environmental problems and their contexts, and proactive efforts to resolve and prevent them; and

- *Integrated solutions*: Integration of a wide range of creative solutions to problems, such as flexible regulation, economic incentives and compensations, negotiated agreements, voluntary actions, and educational programs.

The first two elements capture the balance between the socio-political basis and the scientific basis for decisions. If either element is de-emphasized, the effort is likely to fail. The last two elements recognize the need to view environmental problems broadly, to understand the local context, and to develop appropriate creative solutions that are integrated from a range of options.

There are three basic objectives of collaborative environmental planning. Fundamentally, the objectives help parties look beyond their positions to find shared values (Maser, 1997). The process aims, ultimately to implement a shared vision of the future (Randolph, 2004). They are, as follows:

- *Develop a shared vision*: Collaborative efforts intend for all parties to come up with a vision or direction to which that they can agree and buy into;
- *Resolve conflict*: Collaborative efforts aim to engage all parties in a process of resolving conflict through negotiation and mediation; and
- *Formulate creative solutions*: Collaborative efforts use dialogue and group processes to develop creative solutions that may not have emerged from traditional planning exercises.

Motivation for collaboration is often based on the failings of past planning decisions that have not engaged the public effectively. Pervasive mistrust, declining sense of responsibility and high cost of impasse and conflict are often the result of these past failings. Collaboration has four desired outcomes, all of which have motivated its application (Wondolleck and Yaffee, 2000), as follows:

- To share information and build understanding by educating and learning from one another and engaging in joint fact-finding;
- To make wise decisions and build support for them by addressing common problems and resolving disputes;
- To get the work done by mobilizing resources and sharing management responsibilities; and
- To develop agencies, organizations, and communities by building staff capacities and enhancing social capital and community.

In recent years, there have been an increasing number of cases in which some of the elements of collaborative environmental planning have led to effective planning processes in many different settings (Keuhl, 2001; London, 1995; Porter and Salvesen, 1995; Randolph and Bauer, 1999; Randolph and Rich, 1998). Specifically in regard to siting the location of new ROWs and energy transmission infrastructures, there are also notable success stories (Buchanen, 1995; Mohun and Halverson, 1995; Prier, 1995). For example, Richards et al., (2002), in their study of private-public cooperation in the Dorchester to Quincy Cable Project in Massachusetts, discuss the importance of understanding the local political-social climate existing at the time, and the need for consensus building. The turnaround of the public in this case, from abject refusal to collaborative planning, should not be underemphasized.

It would appear that including collaborative elements in the decision process can benefit all parties involved in the public participation, at least when it comes to locating the best route for a new infrastructure. The focus of this research was the potential for collaborative environmental planning to develop a shared vision for nature conservation on private ROW lands.

EXTENDING NATURE RESERVES INTO ROW CORRIDORS?

There has been increasing pressure for utility ROWs to serve other interests besides the delivery of energy. Landowners now demand greater compatibility between their own goals and use, and the company's needs for a safe, efficient energy delivery system. These linear corridors are expected to provide wildlife habitat, recreational and educational opportunities, and other public and private benefits. There are now numerous examples where ROW corridors are used for multiple purposes from Texas to British Columbia (Buchanen, 1995; Clark et al., 1995; Hurst, 1997; Baker et al., 2000; Harriman and Baker, 2003). Though much work has advanced in the realm of vegetation management, wildlife habitat enhancement, and recreational opportunities in ROWs, it has only been quite recently that the potential for ROWs to protect biodiversity has been explored (Temple, 1996; Yeager, 1996). A 1996 survey of power utility biologists in the United States suggests that terrestrial biodiversity was considered a major issue by only a few utilities (Breece and Ward, 1996). Thus far, partnerships with conservation groups (e.g., Quail Unlimited, Ducks Unlimited, Pheasants Forever, and the Wild Turkey Federation) have taken many forms, but the most common has been to manage the ROW corridor for game species (e.g., quail, rabbit, turkey, and deer). Many non-game species benefit in these conservation arrangements, but the extent is not as well known. The authors of the study predicted that the need to protect biodiversity beyond only game species, and partnerships with local private landowners will become increasingly important for the future. Indeed, studies presented at the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management have shown the beginning of the fulfillment the prediction (Shaefer, 2002; McLoughlin, 2002; Kennedy, 2002; and many others).

There is still much to be learned about biodiversity protection on ROW lands. What is becoming clearer is the fact that the utility industry has a significant role to play in the challenge of preserving biodiversity, and there are an increasing number of examples where biodiversity maintenance is a major influence on the way it does business. It was not the purpose of this research to explore the scientific basis for nature conservation in ROWs, but rather to study the potential collaborative nature planning efforts and their public participation dimensions. Inevitably, such biodiversity-focused collaborative planning efforts will require examining the feasibility of creative new ideas that involve the private landowners.

One such idea, yet untested, is the creation of a nature reserve in an existing ROW corridor, or at least including those ROW corridors into nearby, larger existing nature reserves. Thus, this study sought a location where there was an expressed desire for the creation, or extension, of a nature reserve in a mosaic of private/rural ROW lands to explore the collaborative planning potential.

METHODS

Study area: South Stukely, Quebec

The study was conducted within the rural municipality of South Stukely in Southern Quebec, on an 8.5 km stretch of the 217 kilometer Trans-Quebec and Maritimes (TQM) pipeline route that extends from Montreal to the border with New Hampshire, (Fig. 1).

With a population of 954 permanent residents and 330 seasonal cottagers and a 66 km^2 area, South Stukely has a very low population density (MRC Memphrémagog, 2003). The municipality contains a few dozen small-scale, family-based, dairy and cattle farming and woodlot operations. Except for a few bed-and-breakfasts and artisan shops, there are very few commercial establishments in the area. It is mostly a dormitory community for industrial workers and professionals who commute to the regional centers of Granby, Magog and Sherbrooke (Fig. 1), and a summer vacation area for urban-based seasonal landowners and weekend visitors. South Stukely has a storied past, with French and English settlement dating back to the early 1800s. Numerous buildings, including homes and churches, are valued architectural vestiges of the area's pioneering past. The village is located on *chemin de la Diligence* (Stagecoach Road), what was once the main stagecoach trail between Montreal and New England. This trail is of recognized heritage value and is one of the most picturesque routes in southern Quebec. Only an hour's drive from Montreal and adjacent to a major significant recreation and tourist development, the area is a quiet, "off the beaten path" destination.

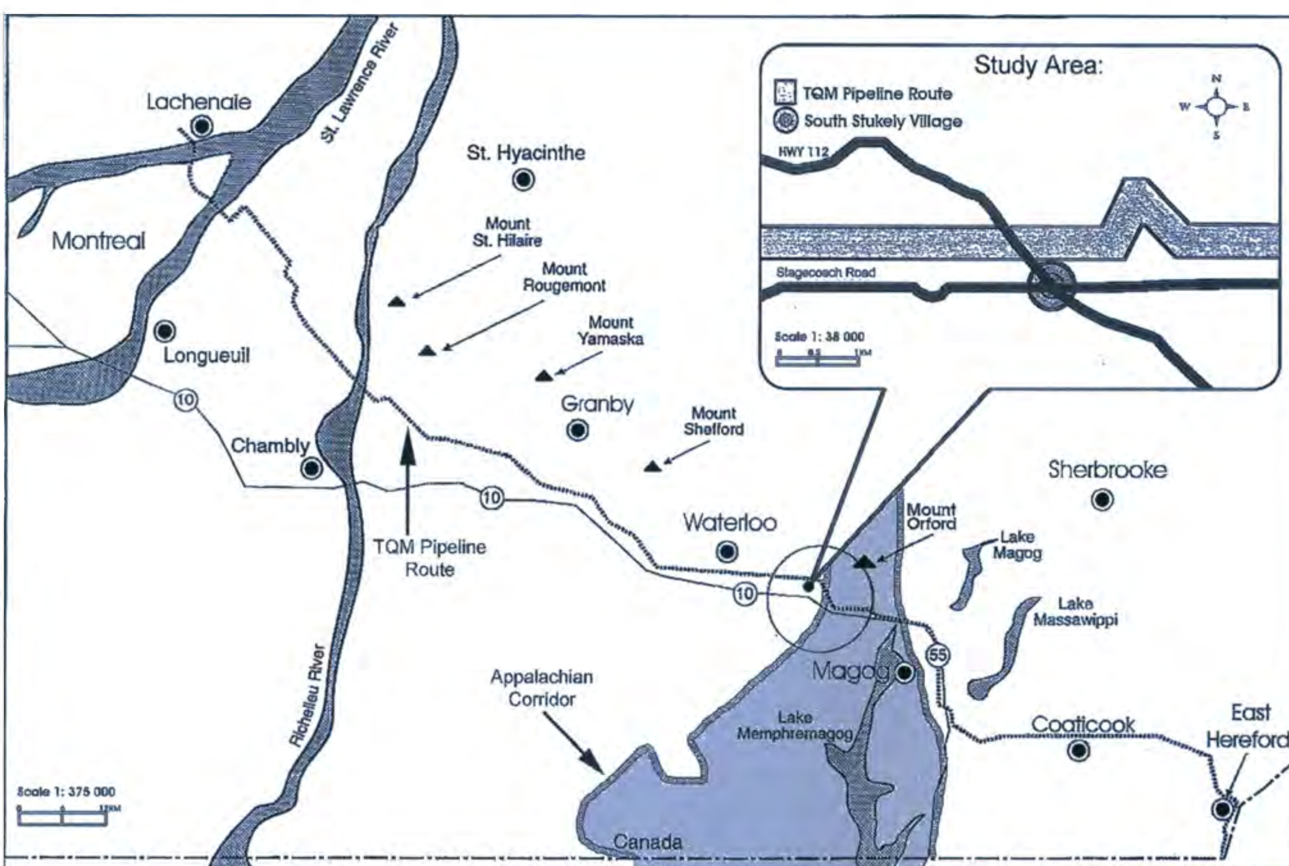

Fig. 1. Location of the TQM pipeline route and south Stukely study area.

Fig. 2. Two pipelines and one electrical transmission line run parallel to Stagecoach Road in South Stukely, Quebec.

South Stukely is also immediately adjacent to one of the largest and most ambitious nature conservation projects in Quebec. The Appalachian Corridor (www.apcor.ca) is a landscape-scale conservation project, an area of over 40,000 hectares of private land (100,000 acres), located in the extension of the Appalachian range north of Vermont (Fig. 1). The area is host to a diversity of highly-valued wildlife species, including black bear, bobcat, lynx, moose, white-tailed deer, coyote, and beaver. Locals have observed a variety of owl and falcon species, as well as a host of songbirds. Amphibians and reptiles inhabit the region's numerous small wetlands. Also found in the area are numerous species of vulnerable or threatened animals and plants, such as the peregrine falcon, the spring salamander, the fisher, wild turkey, wild garlic, and ginseng.

To most that live in South Stukely, and for those who visit, the area's historical, cultural and biological diversity is perceived as the heart of rural southern Quebec and valued for its unpretentious amenities. The TQM pipeline (installed in 1998) runs adjacent to a local distribution pipeline (installed in 1983) and an electrical transmission line (installed in 1947). Together, the three energy ROWs create a corridor over 100 meters wide, which runs parallel to Stagecoach Road, transecting 34 private properties across the rolling hills of forests and farms (Fig. 2).

Document review

To provide an in-depth understanding of the history and the context of the South Stukely case, we examined the publicly-available documentation relating to the planning and construction of the Trans-Quebec and Maritimes natural gas pipeline. This documentation included the project descriptions and environmental impact statements by the proponent, the public report of the Quebec Public Hearing Board and the National Energy Board of Canada, as well as all of the written submissions by the public to both the provincial and federal public hearing processes that affected the South Stukely portion of the pipeline development project. As well, we examined the local newspaper coverage of the project. Information from these documents was analyzed by classifying comments into categories, noting recurring concerns, and exploring common themes. This information served to inform the in-depth interviews we conducted with company and government representatives, affected landowners and community groups.

Interviews

First, we contacted each of the landowners along by the pipeline in South Stukely to set up personal interviews. The interviews were conducted during July and August 2003. The purpose of the open-ended, conversational style, personal interviews was to gather in-

Table 1. Interviews

Private landowners	Pipeline company representatives	Government representatives	Non-governmental groups
32 private landowners with lands transected by the three utility ROWs	Company president Former public local liaison person Current public liaison person	Local mayor Regional county land use planner Provincial Ministry of Environment, regional branch biology officer Provincial Ministry of Environment, official in charge of dossier Provincial Ministry of Natural Resources and Energy, official in charge of dossier	Local coalition of concerned property owners Local Fish and Game Club Regional environmental group Regional Farmer's Union Regional Forestry Producers' Union

formation about the landowners' involvement in and concerns about the pipeline project, as well as their perspective on defining and implement a vision for a nature reserve. We used an interview guide, which divided the discussion in three broad categories, as follows:

1. *Involvement in the South Stukely community*: Duration of property ownership; residency status; place of work; involvement in community such as clubs, volunteer associations, historical societies, etc.;
2. *Involvement in the pipeline project planning & construction phases (1997 & 1998)*: Involvement in provincial and federal public hearings, letters to the editor, protests; concerns about the pipeline construction and maintenance; and
3. *Interest in collaborative nature conservation efforts*: Landowner's current uses of corridor land; concerns with pipeline presence and uses; perspectives on the concept of collaborative nature conservation on their land.

We interviewed 32 of the 34 landowners, making the response rate a very high 94.1%. Only one landowner openly refused to meet with us, stating non-interest as his reason, while another was unreachable. We performed 5 telephone interviews of landowners not living in the area, and 27 face-to-face interviews in South Stukely. Interviews lasted between 30 minutes and 2 hours. All interviews were tape-recorded, or hand notes taken, and later transcribed for analysis.

We also sought the perspectives of other key actors involved, including company and government representatives working closely on the project, as well as various interested non-governmental organizations (NGOs) (Table 1). These individuals were asked questions that related mainly to the third category listed above.

FINDINGS

Document review

The TQM Project and environmental assessment process

During the summer and fall of 1997, several communities in southern Quebec were host to public hearings as part of two government processes, provincial and federal, to authorize the construction of the TQM natural gas pipeline, which would transect from just northeast of Montreal at Lachenaie to the New Hampshire border at East Hereford (Fig. 1). Unlike previous smaller natural gas projects in the area that supplied the local markets, the purpose of the $267 million dollar, 217 km-long, 610 mm-diameter, pipeline was to provide TransCanada Pipelines Limited (TransCan) with natural gas transmission from Montreal to serve the U.S. Northeastern markets (BAPE, 1997). At least 90% of the yearly volumes shipped through the pipeline would be exported to the United States (NEB, 1998). The main justification for the project was that increased competition in the natural gas market made it necessary for Quebec to expand its network by linking the Canadian supply to the markets in the U.S. Northeast via the Portland Natural Gas Transmission System (PGNTS). To remain competitive, the pipeline had to be operational by November 1998. The study zone selected was decisive in determining the project's final layout. On the U.S. side, the original route running via Highwater, Vermont was replaced by a new route through New Hampshire. The advantages on the U.S. side were to circumvent wetlands and watercourses and running nearer to customers. This new U.S. route meant that, in Quebec, the pipeline would be a longer route, running through a green area used for recreational tourism and through numerous wetlands, rivers and streams.

Along the pipeline route, some 440 private landowners, sixteen local municipalities and three regional municipalities or municipalitiés regionales de compté (MRCs) would be directly affected by the new pipeline project. In addition, countless other private landowners and dozens of municipalities and small businesses would be indirectly affected by the project. For this reason, the pipeline project was subject to Quebec's *Environment Quality Act (1978, c. Q-2)*, and the *Regulations Respecting Environmental Impact Assessment and Review (1981, c. Q-2, r.9)*. Because the project had national and international interests, it was also subject to the federal legal counterpart, the *Canadian Environmental Assessment Act (1992, c.37)*, and was placed under the regulatory authority of the National Energy Board (NEB). Although they differ in their procedural details, both the provincial and federal EIA procedures have a similar function: to ensure that the project proponent does its best to identify and eliminate, reduce or

Table 2. Summary of events

Date	Summary of events
1996	
12 November	Trans Québec and Maritimes Pipeline Inc. (TQM) announces to the Québec Environnement Ministry its intention to build a natural gas pipeline from Lachenaie. Québec to East Hereford, near the New Hampshire border
3 December	Québec Ministry of Environnement (MENV) launches environmental assessment procedure under provincial Environnement Quality Act, Environmental and Review Process
1997	
25 March	TQM submits its environmental impact assessment to the Québec Environment Minister
30 April	TQM applies to the National Energy Board (NEB) for a certificate af authorization
9 May	TQM holds mandatory public information sessions to presented the project 22 organizations and individuals petition to Minister to holding of a public hearing
26 May	The Minister of Environment entrusts to the Public Hearing Bureau (Bureau d'audiences publiques sur l'environnement) the mandate to holding a public hearing on the project
16 June–7 August	BAPE holds the public hearings in Montreal, Granby, Magog and East Hereford
11 September	The NEB launches environmental assessment procedure under Canadian Environmental Assessment Act
15 September	The American counterpart of TQM's project, the Portland Natural Gas Transmission System (PNGTS) receives final environmental approval by the U.S. Federal Energy Regulatory Commission
10–24 November	NEB holds public hearings on TQM project in Montreal and in Magog-Orford
1998	
3 April	NEB approves the project
6 May	Quebec Minister of Environment approves the project
10 June	After considerable opposition to its approval of the project, NEB decides to hold a public hearings on the proposed route to consider possible alternative routes
22 July–3 August	NEB holds public hearings in Magog-Orford to consider alternative routes
14 August	NEB approves the detailed route without changes to proposed route
1 November	TQM Pipeline is operational
2003	
11 January	A meeting between different stakeholders is held in South Stukely to discuss the formation of a property-owner's association that would pursue collaborative management of the ROW

mitigate potentially negative environmental and social impacts of the project.[1]

Table 2 presents a summary of the events surrounding the TQM pipeline construction project, including the BAPE and NEB public hearings.

Among the conclusions of the review process, the Quebec Public Hearings Commission stated that it felt "the project is commercially justified in the context of the North American free market and the accelerating phenomenon of convergence in the energy supply sector" and that the local economic spin-offs would be substantial but "limited to the nine-month construction period." However, it felt the proponent had not shown that the longer layout chosen was optimal, since TQM "did not question the route chosen by its U.S. partner, complete with the border point of interconnection and impacts either side of the border were not compared." Moreover, the commission stated that a permanent 18-m-wide right-of-way such as the one authorized in the U.S. would be more appropriate than the 23-m right-of-way requested by TQM. Most importantly, since the commission considered "the project to be of a private, commercial nature, there are no legitimate grounds for forcing citizens to allow a gas pipeline to run through their property when it is not essential for the common good." It also suggested the adoption of a policy for compensating moral, psychological and aesthetic damages in addition to the usual land compensation. The Commission's final recommendation was that "new means of compensation could be explored, i.e. participation in business profits, so that landowners are associated with the project as partners and customers."

For its part, the federal environmental review board, which also included public hearings, felt that the project was justified economically and environmentally. It concluded "with the proposed mitigative measures, the project would not be likely to cause significant adverse environmental effects." In the end,

1 Further details about both environmental impact assessment procedures can be found at the following websites: For the federal procedure, go to www.ceaa-acee.gc.ca/, and for the provincial procedure, go to www.menv.gouv.qc.ca/programmes/eval_env/regproc.htm.

the project went ahead as first planned and was constructed by the deadline of November 1998.

Public hearing briefs and local newspaper reports
The proposal to construct the TQM pipeline was not well received by a majority of people that wrote briefs to the provincial and federal public hearings boards. Of the 73 briefs submitted to the public hearings by private landowners, local municipalities, and non-governmental organizations, 72 of them presented arguments in opposition to the construction project. In a brief submitted to the provincial hearings in Magog, a coalition of South Stukely landowners stated:

> "... it is our hope that the Commission will consider the various options before allowing TQM to ruin some of the last pristine landscape in a region which is recognized as an outstanding four-season destination for eco-tourism."

Stating numerous historical, environmental and quality of life arguments to oppose the pipeline, the coalition of landowners questioned the wisdom in not exploring other siting options:

> "One of the most distressing aspects of this application to put a pipeline on our land is the lack of respect for private ownership. It has, by its own admission, not considered or sought out any other route. It has taken the line of least resistance, and planned the pipeline where there are already Hydro-Quebec and Gaz Metropolitain rights-of-way. As good neighbors and good citizens in support of the 'greater good,' we reluctantly agreed to the passage of the last pipeline. This was apparently all the planners of this project needed to enlarge upon the precedent. In other words our sense of service to our society at large is now being used against us. We were bamboozled into accepting the first pipeline ... and this fact is being used now to justify a second corridor, and probably others in the future."

Though TQM provided monetary compensation to landowners to offset the potential damages incurred by the pipeline that would enlarge the existing corridor by another 23 meters, several landowners expressed their dissatisfaction with the amounts offered:

> "Many affirmed that the compensations offered were insufficient compared to the loss of quality of life and quietness" (BAPE, 1997).

It seemed, from the documentation relating to the public hearings, that there were several aspects of the project opposed by an overwhelming majority of landowners. Local newspaper coverage on the pipeline proposal was also rife with landowner concerns about the potential impacts of the projects. Headlines in the local daily newspaper, *The Record*, show evidence of the landowners' persistent opposition throughout the planning and construction process, as follows:

- "Landowners angry about TQM pipeline project" (Aug 11, 1997);
- "'No thanks' to gas pipeline – landowners" (September 15, 1997);
- "Towns take opposition on gas pipeline" (November 6, 1997);
- "Pipeline project moves full speed ahead – landowners miffed they weren't informed of decision" (April 7, 1998);
- "Landowners' coalition loses pipeline appeal" (April 23, 1998);
- "NEB tribunal refuses petition to stop TQM construction" (July 29, 1998);
- "Landowners seek injunction to stop work" (August 13, 1998);
- "Court gives greenlight to TQM project" (September 8, 1998); and
- "Landowners complaints against TQM mount" (September 29, 1998).

Most of the complaints reported in the newspaper articles related to damage to water supply and other sensitive environmental resources. Some landowners also expressed the hopelessness and anger about the lack of impact of their input into the decision process, as is the following quote:

> "The government has only held these public hearings for appearances and everything was decided beforehand ... it would be better if the government hadn't mislead us from the start" (Legault R., 1998).

This document review helped develop an understanding of the issues and concerns throughout the pipeline's planning and construction phases. The interviews we conducted aimed, on the one hand, to revisit the issues and concerns about the pipeline construction project; and, on the other hand, to explore stakeholders' perceptions about the potential for establishing a nature reserve on private ROW land through collaborative planning efforts.

Interviews
Analysis of the 45 interviews revealed 6 dominant barriers impeding the potential for collaborative nature conservation efforts in the South Stukely energy corridor. These barriers include the following:

1. Ill-defined goals;
2. Limited community cohesiveness;
3. Inadequate communication;
4. Lack of trust;
5. Procedural inflexibility; and
6. Changing role of the public (institutional framework).

Each barrier is discussed in detail next.

Barrier 1. Ill-defined goals
A key theme which emerged from all interview responses is that there were ill-defined and potentially competing goals regarding the potential for establishing a nature reserve. Comments from a sample of respondents indicate that this barrier manifested itself very clearly in a number of ways. For example, when asked what respondents though the goal of collaboration might be, one respondent answered (each respondent is identified by a single letter to maintain confidentiality):

> "More citizen civility and awareness about what we might collectively possess in the face of developmental pressure" (respondent R).

While preventing future development pressure seems to be an important goal, the unfortunate reality is that the idea of collaboration remained foreign to some stakeholders. For example, another respondent replied:

> "We have not seen anything more than the idea [of the nature reserve], which has not really been put forward in terms of anything specific as of yet" (respondent H).

In the face of this unclear goal definition, many respondents put forth their own goals for the collaborative nature reserve idea:

> "Right now we fear that it will become a public space. We are really concerned by the fact that this piece of land is being used without our consent and that it could be used even more in the future ..." (respondent AG).

Another respondent claimed to have a clear understanding of the nature reserve until we presented him with what other respondents had told us. Then he replied:

> "It [the nature reserve] could be something that worries me a little bit. The more we talk, the more I find small concerns" (respondent L).

One respondent, who is a hunter, saw the nature reserve as being a neighbor's way to stop hunters from hunting:

> "I think he doesn't want us to have the right to hunt. He wants us to stop hunting" (respondent P).

When asked how they felt if the government proposed a 4th ROW on their land, the replies were overwhelmingly against the idea. We include here a sample of all responses:

In favor of more ROWs on their land:

> "Sure, bring 'em on" (respondent P).

Ambivalent to the idea:

> "I don't know, it depends on how much it pays" (respondent L).

Against:

> "I would say yes, it would bother me. It is certain that we live in society, but we should share equally our social responsibilities. If the creation of a wildlife zone into the corridor could stop that, I would like it. I think that there are enough ROWs... Up to now, there are two pipelines ... there are contamination and leakage risks. I would not like to end up with 7 or 8 pipelines, so the wildlife corridor is good for that" (respondent G).

Barrier 2. Limited community cohesiveness
The rural community of South Stukely, described earlier, is large and dispersed. Though many landowners have the pipeline corridor in common, they do not share much else. Because many landowners are only seasonal residents, the cohesiveness of the community is limited. This adds another barrier to the potential for collaborative nature reserve planning. Landowners whose permanent residence is in Montreal had this to say:

> "We never seem to be around at the right time. We are sort of a little bit aware of the project, I guess not fully knowledgeably" (respondent H).

> "We would like to become involved here in many things, but we cannot because we don't live here" (respondent PB).

Even those who live in the area and earn their living from the land find that there is not much of a sense of community:

> "I am not involved [in the community] because there is no organisation to be involved with. We don't have baseball and we don't have a skating rink anymore" (respondent P).

Reflecting on the former community cohesiveness that existed in opposition to the pipeline project, one respondent stated:

> "There was a time when neighbors were joined together to fight the pipeline giant. But different and changing interests, as well as exhaustion from losing the battle against TQM have caused the neighbors to go their own ways" (respondent C).

The effects of absenteeism and lack of community cohesiveness are that people do not have close relations with their neighbors, a fact that, according to some respondents, was used by the pipeline company against landowners:

> "Some were bought off, many before they even realized there was any opposition [to the pipeline construction project], because one of their tactics was to tell a landowner that all his neighbors had signed. Since communities are not as cohesive as they used to be, this often worked" (respondent R).

Barrier 3. Inadequate communication

Communication is central to any relationship. The interview responses indicated that inadequate communication between the company and landowners, as well as between landowners themselves was a key barrier to the potential for collaborative nature reserve planning. Here, historical conflicts between landowners and the pipeline company played an important role in the potential for collaboration.

Several respondents had serious complaints about the consultation process during the pipeline planning and construction phases:

> "When they say that they consulted us ... a consultation is not a discussion with you to give you facts, a consultation is asking for your point of views and to exchange ideas" (respondent PB).

> "They ask you for your view but not to listen to you. Even if you say no, the government will go through [with their proposal] anyway" (respondent M).

At the same time, some landowners who had expressed support for the project found that their opinions were not listened to by other South Stukely residents:

> "After discussing the project with the landowner association, I realized that the government was listening more to what I had to say, than were my neighbors, whose sole purpose was to redirect the pipeline into somebody else's backyard" (respondent A).

Many respondents believed that the communication process worked more in favor of the pipeline company and regulatory authority than the landowners:

> "We were calling the NEB [National Energy Board] to get some information and the first thing we knew, TQM [pipeline company] had it before us. I am compromised everywhere, everywhere in the ladder of power. Because people have access to information before me, they are always more prepared than me" (respondent PB).

Barrier 4. Lack of trust

Interview respondents in our study revealed deep concerns about trust. The majority did not believe that the environmental impact assessment was a true reflection of the best available science. Rather, several felt the impact assessment process, including the public hearings, was simply one of the procedural obligations to get the pipeline approved. Several complained about the "paternalistic attitude" taken by company officials to anybody with an alternative view about the possible environmental impacts of the proposal, as one respondent claims:

> "I was standing like a criminal in front of the NEB [National Energy Board]. You have not done a thing and you have to defend yourself, you are the culprit. Before them, you really are the culprit. To them, we bring their business to a standstill" (respondent B).

There was a climate of mistrust about even the very practical, identifiable aspects of the maintenance of the pipeline after it was built. Although people were told by a company representative that herbicides were not going to be used on the ROW and that vegetation control was only to be carried out mechanically, one respondent told us:

> "They come and apply herbicides without notice. At first, in the first years, we were seeing something that reminded me of Vietnam and the Agent Orange they used" (respondent M).

This statement was refuted by a company representative who stated: "it's TQM's policy not to use herbicides." Regardless, the main factor that drove the mistrust was the negative attitude that was demonstrated by the company. Trust must go both ways for collaboration to work. The idea of creating a nature reserve, without a foundation of trust between collaborators, can be treated with suspicion. Reminiscing about the pipeline planning phase, the representative from the provincial Ministry of Natural Resources said:

> "It was an epic battle ... there were some who would not agree to anything we offered. It is probably them that are starting the nature conservation project. Do they think that they will get more money out of it?" (respondent B).

Conversely, a landowner advancing the idea of a nature reserve on the ROW told us:

> "It is not the amount of money that will attenuate the environmental impacts" (respondent PB).

Barrier 5. Procedural inflexibility

The respondents identified numerous barriers regarding flexibility that involve time, funding, and a lack of sufficient manpower relating to the decision-making process. The barrier of inflexibility affects all stakeholders, including the company, the regulators, and the landowners. Here we focus on a few examples only. Regarding the landowners' suggestion that the pipeline be constructed nearer to the highway instead of through the middle of their private lands, the government representative stated:

> "The pipeline company was scared of crafting a precedent [by investigating the feasibility of locating elsewhere]" and "it is the government policy to favor co-location of ROW wherever possible" (respondent B).

In his mind, locating the pipeline right through communities, instead of away from them, had positive repercussions:

> "It's good to have a pipeline because it gives municipalities a chance to have an emergency plan" (respondent B).

In other words, the project proponents felt that it was the landowners that should be more flexible to see these potential benefits, not the company. Under rigid time constraints imposed by the pipeline approval process, some landowners felt they were at a disadvantage against the proponents regarding time, expertise and funding to adequate prepare themselves:

> "Unfortunately, we did not realize that the time to get organized was then, that we needed research then, and that we would need legal advice right away – and probably, it would have made no difference" (respondent R).

These interviews indicated that, in many ways, procedural obligations of the pipeline approval process were constraining the public participation aspect of the planning process. It is important to learn from past mistakes. Innovation requires flexibility. It must therefore be understood that for a nature reserve to become established on a ROW, there must be some willingness on the part of the company and the government regulators to allow landowners to take the time to properly study the proposal, to advance new proposals of their own and to acquire the necessary funding and expertise. This brings up the final barrier we encountered which is discussed next.

Barrier 6. Changing role of the public (institutional framework)

The most complex barrier is one that regroups many aspects of the changing role of the public in the institutional decision-making framework. Increasingly we are seeing a more active and organized civil society and the questioning of government's ability to make decisions in the public interest. Perhaps most fundamental, is the changing role of the power of individuals within civil society to make a difference in the public sphere. Nearly every interview respondent described barriers that involve values, goals, and assumptions about the role of the public within the institutional framework of the planning organizations. A key barrier to any potential for future collaborative planning was the overwhelming disillusionment about their role in the institutional decision-making framework. Referring to the public consultation process over the proposed pipeline:

> "What is so infuriating in all this, they [they provincial public hearings commission] agreed with us about 98 or 99% of the time, but the BAPE has no power so the government just trashed their report. It cost us several millions for absolutely nothing. We proved all our points, but the pipeline just went through anyway" (respondent B).

> "The people of the BAPE, they looked as if they were saints, but my respect for them went downhill. I find that these people are well remunerated to do a good study, they worked hard, they listened to what people had to say, they delivered good decisions, they write great reports, but it is always on a consultative base. I find that in that sense, the government is mocking us" (respondent P).

> "That fact that we won at the BAPE did not help us. People were thinking "we are good, we will go to the NEB and win again and even use the BAPE report to win at the NEB. But it did not go that way. We realized that it was not working like that. I wish that in the future, if we do more BAPE hearings, and it cost a lot of money, we should further respect the BAPE decision" (respondent D).

> "It is a travesty of democracy" (respondent M).

In light of this, some questioned the government's ability to protect their rights as property owners:

> "The government comes and they take a piece of land whether I like it or not. They just took it, one hundred feet wide; that is what their corridor is. Like a guy told me once "I don't care what you do, take us to court, we are going through right now" (respondent S).

> "Today, nobody is at home anymore, and it's like that everywhere" (respondent M).

Within this climate of disillusionment with government, and its role in democratic decision-making, the public may find it very difficult to believe it can foster successful collaboration in the future.

DISCUSSION AND IMPLICATIONS

The nature reserve has not yet been established, and the barriers that have been identified in this study deeply relate to the animosity that has existed between landowners and the pipeline company. Why does collaboration not occur? Most of the literature on collaboration views human behavior as motivated largely by self-interest, and cooperative arrangements develop because they are mutually beneficial. What has become clear from the study of the South Stukely case is that the establishment of the pipeline corridor was not beneficial to all parties involved. Although financial compensation was provided to landowners to offset the damages incurred by the addition of the new proposed pipeline, the evidence from the document review and interviews suggest the compensation did little to ease the massive local opposition. The in-depth case study revealed that the manner in which the public consultation aspect of the planning phase took place was divisive and insufficient to address the local needs. Instead, the public process only seemed to provide regulatory support for a project that was not going to be disapproved.

But this does not have to be the end of the story. If collaboration is intended to be beneficial to all parties, the idea of establishing a nature reserve on the ROW in South Stukely could still have a lot of merit. Furthermore, since motivation for collaboration is often based on the failing of past planning decisions that have not engaged the public effectively (Wondolleck and Yaffee, 2000), then the South Stukely case is the ideal grounds to explore collaboration. Ideally, all parties would explore whether the creation of the nature reserve is beneficial to them. Then they would collectively craft a shared vision that they would all buy into. With this shared vision, conflict would be resolved and creative solutions enabled.

Unfortunately, as we have seen in the South Stukely case, the adversarial planning approach can lead to poor relations between the company, the government regulators and the public. Our study identified several barriers to any progress in attempting new approaches to collaboration that would see an eventual nature reserve established in South Stukely. It is unlikely that these barriers occur independently. In fact, we suggest that the common thread that links all the barriers together is the inability of the existing planning framework to foster a sense of responsibility and commitment of all parties. The barriers we discovered in the South Stukely case, in our judgment, reflect underlying fundamental problems in the paradigm of planning that has traditionally been followed by governments and the energy industry. The dominant paradigm of ROW planning has been molded by a comprehensive rational approach, a design that views planning as engineering, a conception that planners hold a technical expertise to solve socially problematic challenges, and an assumption that their actions represent the broad public interest (Lachapelle et al., 2003). This kind of approach sees the public as largely ignorant, or fickle, and perhaps even as a necessary hurdle to overcome in the regulatory approval of what planners perceive as an already well-designed project. Paradoxically, despite the increased opportunities to involve the public, the public feels more and more disfranchised from the process.

By shifting the planning paradigm toward a more deliberative and collaborative approach, instead of relying on the more adversarial public hearing procedures, we may be able to open venues for exploring innovative solutions. In the South Stukely case, the emphasis on seeing a nature reserve on the ROW for its joint benefits to all parties involved would move the discussion away from one characterized by the traditional "us" versus "them" debate to one of developing common ground and compatible interests. Unfortunately, not everyone is willing to explore this untested approach because of the hurts of the past. The barriers we identified in our study were deeply rooted in past experiences.

Yet the idea of the collaboratively-established nature reserve on a ROW still has potential. All of the barriers we identified can be removed if those involved are willing to see the benefits of doing so. By developing a shared goal that is well-defined, by fostering community cohesiveness around the shared vision, by ensuring open and transparent two-way communication, by re-establishing trust, by willing to be flexible and positive, and by embracing the changing role of the public in decision-making, the potential might be realized.

By analogy, the paradigm shift in planning rows is akin to changing the direction of a large ship heading toward an iceberg. Unless we see the benefits of changing the ship's direction in time, and making real and practical steps to change our direction, we will inevitably have to deal with the consequences of a collision. Collaboration presents a serious challenge to conventional wisdom. Because of the evidence we found in our study, we believe collaboration should be attempted in situations like the South Stukely nature reserve case, despite the barriers, precisely because it holds out the possibility of bringing forth new knowledge and ideas capable of creating and legitimating new interests, reshaping our understanding of existing interests, and, in the process, influencing the pathways along which power travels. No pun intended.

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REFERENCES

Baker, D., J. Souras, and J. Harriman. 2000. Integrated resource management for electric utility transmission right-of-way. Paper presented to the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB.

BAPE (Bureau d'audience publique sur l'environnement). 1997. Rapport d'enquête et d'audience publique: Project de gazoduc entre Lachenaie et le réseau PNGTS. Québec: BAPE.

Bardati, D. 2004. Letter from South Stukely: Nature to get right-of-way. Alternatives Journal: Canadian Environmental Ideas and Action, 30(2): 7.

Bourgeois, C. and D. Bardati. 2004. La gestion environnementale participative des servitudes d'énergie dans la municipalité de Stukely-Sud. Revue d'études des Cantons de L'Est, 24: 87–92.

Breece, G.A. and B. Ward. 1996. Utility terrestrial biodiversity issues. Environmental Management, 20(6): 799–803.

Brown, T. 1995. Cooperative management of utility corridors in Canada. Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, QC, 19–22 September 1993, pp. 343–350.

Buchanen, S. 1995. Cooperative strategies for rights-of-way management. Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, QC. 19–22 September 1993, pp. 3–4.

Carr, D., S. Selin, and M. Shuett. 1998. Managing public forests: understanding the role of collaborative planning. Environmental Management, 22(5): 767–776.

Cherry, P. 1997. Townships landowners angry about TQM pipeline project. The Record, August 11, p. 1.

Clark, B., J. Fly, D. Buehler, and R. Evans. 1995. Public perception of powerline right-of-way management. Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, QC, 19–22 September 1993, pp. 446–449.

Harriman, J. and D. Baker. 2003. Applying integrated resource and environmental management to transmission right-of-way maintenance. Journal of Environmental Planning and Management, 46(2): 199–217.

Healey, P. 1997. Collaborative Planning. Hampshire, England: Macmillan.

Hurst, G. 1997. Project habitat: ROW management to enhance wildlife habitat and utility image. Proceedings of the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, New Orleans, Louisiana, 22–26 February, pp. 311–315.

Kennedy, A.J. 2002. Developing a species at risk conservation plan: The Thicksilver Pipeline Experience. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB. pp. 411–420.

Keuhl, D. 2001. From Collaboration to Knowledge: planning for Remedial Action in the Great Lakes. Ph.D. diss. Environmental Design and Planning, Virginia Tech, Blacksburg, Virgina.

Lachapelle, P., S. McCool, and M. Patterson. 2003. Barrier to effective natural resource planning in a "messy" world. Society and Natural Resources, 16: 473–490.

Legault, R. 1998. Apr 23. Landowners Coalition Loses Pipeline Appeal. The Record, (Sherbrooke, Quebec), p. 3.

London, S. 1995. Collaboration in action: A survey of community collaboratives. A paper prepared for Pew Partnership for Civic Change.

Maser, C. 1997. Resolving Environmental Conflict. Delfray Beach, FL: St. Lucie Press.

McLoughlin, K. 2002. Endangered and threatened species and ROW vegetation management. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB. pp. 319–326.

Mohun, E. and D. Halverson. 1995. Reconciling aboriginal and industrial interests in right-of-way management, Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, QC, 19–22 September 1993, pp. 5–6.

MRC Memphremagog. 2003. South Stukely Panorama. Tourist brochure.

NEB (National Energy Board of Canada). 1998. Comprehensive Study Report: Trans Québec & Maritimes Pipeline Inc - PNGTS Extension. GH-1-97. Calgary, AB: National Energy Board of Canada.

Porter, R. and D. Salvesen. 1995. Collaborative Planning for Wetlands and Wildlife. Washington, DC: Island Press.

Prier, P. 1995. A successful method for incorporating public input into pipeline route planning in Ontario, Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, QC, 19–22 September 1993, pp. 7–9.

Randolph, J. 2004. Environmental Land use Planning and Management. Washington, DC: Island Press.

Randolph, J. and M. Bauer. 1999. Improving environmental decision-making through collaborative methods. Policy Studies reviews, 16 (3/4): 168–91.

Randolph, J. and R. Rich. 1998. Collaborative environmental management: An emerging approach and experience in Virginia. Virginia Issues and Answer, 5(1): 11–19.

Richards, F.P., F.S. Smith, J. Amodeo, and M. Mills. 2002. Public-private cooperation in electric transmission line siting, the Dochester to Quincy Cable Project: A case study. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB. pp. 807–818.

Shaefer, V. 2002. Rights-of-way management in support of biological conservation. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB. pp. 303–308.

Temple, S. 1996. Ecological principles, biodiversity and the electric utility industry. Environmental Management, 20(6): 873–878.

Vierima, T. and J. Goodrich-Mahoney. 2002. Right-of-way communication strategies. Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, AB. pp. 791–795.

Wondolleck, J. and S. Yaffee. 2000. Making Collaboration Work: Lessons from Innovations in Natural Resource Management. Washington, DC: Island Press.

Yeager, K. 1996. The exuberant planet: A global look at the role of utilities in protecting biodiversity. Environmental Management, 20(6): 967–971.

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Part XIII
Regulatory Compliance

Helms-Gregg 230 kV: Successfully Negotiating the NEPA Process

Pamela R. Money

In the mid 1980's, PG&E stopped using herbicides on USFS property due to their moratorium. PG&E had just completed construction of the controversial Helms Pumped Storage Facility, which required the clearing of approximately 21 miles of right-of-way through Sierra National Forest land for the construction of the Helms-Gregg 230 kV transmission line. As part of the original FERC license, a Wildlife Agreement between PG&E and the State of California was reached in 1978, which required PG&E to develop a Wildlife Habitat Plan in cooperation with California Department of Fish and Game, the USFS, and the USFWS. Even though this wildlife habitat plan included the use of herbicides, they were never used and the plan was never fully implemented. Up until 1999 only minimal vegetation work occurred. By this time the vegetation density and height had reached a critical stage and PG&E approached the USFS regarding the need for a comprehensive vegetation management plan. This ultimately led to the preparation of an Environmental Assessment to re-establish the ROW and the re-introduce herbicides as part of an Integrated Vegetation Management on the Sierra National Forest.

Keywords: NEPA, integrated vegetation management, environmental assessment, right-of-way

INTRODUCTION

Pacific Gas and Electric Company (PG&E) submitted the license application for the Helms Pumped Storage Facility to the Federal Energy Regulatory Commission (FERC) on September 24, 1973. A 50 year license was issued on May 18, 1976. PG&E completed the construction of the 1,212 MW Helms Pumped Storage facility in 1984 which included two 230 kV transmission line. The transmission line right-of-way (ROW) crosses both Sierra National Forest (SNF) land and private land. This consists of a 200 foot wide ROW (for two single circuit tower lines) from the switchyard west for approximately fifteen miles where it changes to a 120 foot wide ROW (for one double circuit tower line) from that point west to the Gregg substation. The first 21 miles of the right-of-way cross Sierra National Forest land beginning at an elevation of 7300 feet and ending at an elevation of 2100 feet. The ROW includes less than 450 acres of SNF property out of a total of more than 1.3 million acres.

FERC license requirements

The Helms project was subject to FERC license requirements that were fairly stringent at the time. These included the following:

- Utilize planting of vegetative screens and right-of-way vegetation management to further mitigate the adverse visual impacts of the transmission line;
- Special construction techniques to protect vegetation;
- Surveys and appropriate action to protect rare and endangered species, pursuant to the Endangered Species Act of 1973; and
- Develop a Wildlife Habitat Plan.

Implementation of some of the license requirements was accomplished without thorough consideration of the potential impact on future maintenance, and ultimately resulted in the creation of additional vegetation management challenges.

Planting vegetative screens

Unfortunately, the vegetation that was planted included both Ponderosa pine (Pinus ponderosa) and

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Black Oak (Quercus kellogii), both of which are tall growing species that are unsuitable for transmission line rights-of-way.

Wildlife Habitat Plan

A Wildlife Habitat Plan was proposed in the Helms Pumped Storage License Application to the Federal Energy Regulatory Commission in 1973. The resultant plan was developed with the assistance and cooperation of the Sierra National Forest, the California Department of Fish and Game (CDF&G) and the U.S. Fish and Wildlife Service (USF&WS) in 1978. This plan allowed for the following maintenance techniques to be considered for use in managing the ROW vegetation:

- Trimming to eliminate invading brush in grass converted chaparral areas;
- Marking and prescribing tree and brush species to be removed;
- Evaluating the use of snags before removal. Snags that pose a threat to transmission facilities must be removed;
- Fertilizing and replanting areas, which have eroded or become nonproductive;
- Maintaining culverts, and habitat type conversions;
- Removing encroaching conifers from designated meadows along the right-of-way;
- Preserving and encouraging brush establishment on edge of meadows, along the right-of-way; and
- Periodic application of approved herbicides.

This plan also resulted in the formation of the Wildlife Management Team (WMT) that consisted of one representative from each of the following: PG&E, SNF, CDF&G, USF&WS, and the Fresno County Sportsmen's Club.

Construction issues

In 1981, there was a major diesel fuel spill into Wishon Reservoir, and in 1982 one of the penstocks ruptured. Both accidents resulted in significant adverse impacts upon the fish and wildlife resources of the project area. The 1982 incident involved a ruptured 22-foot diameter conduit that released a flow of water affecting approximately 73 acres of forest and riparian vegetation along two creeks. PG&E developed plans for mitigation and monitoring activities in conjunction with the SNF, the CDF&G, and the Water Quality Control Board (WQCB). These plans included rechanneling one of the creeks, erosion control, slope stabilization, revegetation, streambed restoration, native trout stocking, fishery habitat improvements, contributions to the USFS for a superior tree improvement program and archaeological testing, and a monitoring component. These accidents negatively affected PG&E's relationship with the SNF.

Post construction issues

From the time the right-of-way was cleared for construction until the late 1990's, very little vegetation management occurred even though it was allowed for in the Wildlife Habitat Plan. Many of the components of the Wildlife Habitat Plan were simply never implemented. Additionally, in 1985 all of the road permits were intentionally closed out after the construction and access became more limited as the roads degraded over time.

PG&E's relationship with the SNF degraded as well. The SNF restricted what vegetation management activities they would allow and PG&E responded by directing crews to perform unauthorized work. As a result of that, the SNF requested that PG&E prepare a vegetation management plan in 1995. PG&E began actively working with the SNF to develop a comprehensive vegetation management plan. In 1998, the SNF was frustrated that the plan was not complete and limited approved activities to limbing or topping of vegetation to achieve required clearances. Numerous conflicts occurred between the SNF and PG&E and the plan was still in draft stage in 1999. The SNF and PG&E could not agree on when trees should be removed instead of topped. Conflicting goals and a lack of trust complicated the situation. By 1999, the vegetation was approaching a critical height and density (Fig. 1) and completing the plan became critical. On the single PG&E owned parcel, over 16,000 trees were removed on just 10 acres of ROW. It was virtually impossible to tell which tree was closest to the conductors without climbing one of the trees.

The SNF direction in 1999 was that once the vegetation plan was completed there would be no additional environmental work required as long as the vegetation plan was compatible with the initial Wildlife Habitat Plan. In 2000, emergency tree work occurred in order to ensure that PG&E was in compliance with all applicable clearance requirements. A first draft of the vegetation management plan was submitted in 2000. Upon reviewing the plan the SNF made the determination that it would be necessary for PG&E to complete both a Biological Evaluation and a Biological Assessment. Later that same year the SNF and PG&E agreed that the WMT would work with PG&E to complete span by span vegetation management prescriptions as part of the plan. As the vegetation plan progressed, the WMT expressed concerns and the SNF determined that it would be necessary to complete an Environmental Assessment (EA) in order to satisfy National Environmental Policy Act (NEPA) requirements.

Although herbicides were not included in the 2000 version of the vegetation plan, the intention was that PG&E would pursue the use of herbicides once the ROW was cleared. However, once the SNF determined that an EA would be necessary in order to clear the ROW, the decision was made to include herbicides as part of the proposed action. Preparation of the EA began in earnest in the fall of 2000.

Fig. 1. Helms-Gregg 230 kV ROW in 1999.

NEPA

The National Environmental Policy Act (NEPA) and how it impacts ROW management on federal property was well described by Norris (1999). Basically, vegetation management activities on ROWs on federal property are subject to NEPA. Implementation of NEPA is expensive, time consuming, and tedious, but when done carefully, methodically, and collaboratively it can result in a successful outcome. The process is well defined, and cannot be circumvented.

When the USFS determines that in order to satisfy NEPA requirements, that an Environmental Assessment (EA) is necessary, numerous challenges are the result. Some of the challenges in working with NEPA are due to the time required to complete the necessary surveys (biological, botanical, and archaeological), and to prepare, review and revise the resulting environmental document. Because of the lengthy process, changes can occur to any of the following: personnel involved with either preparing or reviewing the document; budget; listed species; and related management plans. All of these changes can result in additional delays.

THE VEGETATION MANAGEMENT PLAN

The Vegetation Management Plan became the starting point for the EA. PG&E had first discussed developing a vegetation management plan in 1995. Very little progress was made until 2000 when the first vegetation plan was developed. This plan was completed at the direction of the SNF High Sierra District Ranger and without any input from the WMT. After reviewing the plan the WMT expressed concerns and an interest in being involved in the revising the plan. PG&E, the SNF and the WMT agreed to jointly revise the vegetation management plan. This required numerous meetings with the WMT to develop the prescriptions for each individual span of the 21-mile long ROW. Initially these meetings were contentious and unproductive. This was complicated by a number of changes and challenges that occurred during this process.

Changes and challenges

This time period represented an almost continuous series of changes within both PG&E and the SNF. Changes included the following:

- PG&E Separation Project;
- California Deregulation;
- Creation of the California Independent System Operator;
- USFS Sierra Nevada Framework;
- 6 Different SNF Lands Officers between 1996 and 2004;
- 2 Different Lead SNF Biologists;
- 3 Different Lead PG&E Biologists;
- PG&E Reorganization in 2000;
- California Energy Crisis 2000–2001; and
- PG&E Bankruptcy 2001–2004.

These changes delayed the process even further and increased the challenges. One of the biggest challenges for both the SNF and PG&E was the lack of trust and poor communication that had occurred since the original construction. The SNF was content with the status quo and PG&E could not continue to accept it. The process had hit a veritable impasse.

Prior to preparing the Helms Gregg EA, PG&E had recently completed two different EA's that included the use of herbicides on two different USFS forests, and had learned a great deal in the process. This also increased the time required to prepare the EA since one of the most critical lessons learned was that the EA needed to be very clear so that it could be implemented by anyone, even someone that was not involved in the preparation. Additionally, it was important to PG&E to ensure that the document allowed for some flexibility.

Strategy

Clearly none of the past approaches had been successful nor would they be going forward. In order to effectively work together to develop a collaborative solution a different approach was necessary. The strategy that was utilized and ultimately proved to be successful was based on the following:

- Careful selection of the project team;
- Stick to the science;
- Clear, consistent message;
- Build consensus;
- Build trust;
- Follow through;
- Patience;
- Conflict resolution; and
- Build on past success.

Each of the above items was an equally important element of the strategy. Selecting PG&E project team members that could work together, understood the need for the project, and supported the project was critical. Since there had been a contentious relationship with the WMT it was important that the project team be able to present a united front. It was also helpful that some of the members had established working relationships with members of the WMT. The goal was to base as many of the decisions about the vegetation plan on the scientific facts and to present a clear consistent message about every aspect of the project. Research presented at prior International Symposia on Environmental Concerns in Right-of-Way Management proved invaluable in this regard. In order to build consensus, it was important to identify those individuals that shared common goals even if they were not part of the project team, such as the USFS District Fuels Officer, the District Timber Management Officer or the Special Uses Officer. These individuals were involved in the preparation of the vegetation plan, and their support proved extremely valuable. Trust was built slowly, largely by following through on commitments. Each success helped build towards the next success. Common goals were identified and slowly many of members of the team began to see that the project would be beneficial to everyone. The USFS District Ranger was effective in resolving the few conflicts that the team could not resolve internally. Over the course of several months, the relationships improved dramatically and allowed for collaboration and the development of the Vegetation Prescriptions (Table 1).

The table includes the information that was included in the original 1978 Wildlife Habitat Plan and the current vegetation management prescription. Prescriptions were site specific and based on existing conditions. The vegetation plan became the basis for

Table 1. Vegetation prescriptions

Location	1978 wildlife habitat plan direction	2004 vegetation management prescriptions
Milepost 0 to 14	In this section, the right-of-way is 200 feet wide. Particular attention will be made in the clearing operations to leave existing shrubs and forbs along the perimeter of corridor to establish proper "edge effect" for wildlife. See Fig. 1. Approximately 169 acres of "edge" will be created by the clearing operation.	Switchyard to T/4: Manually remove conifers (mainly lodgepole and jeffery pine). Create brush piles with all resulting debris for habitat. T/4 to T/7 Mechanically clear wire zone except in rocky areas. Manually remove trees in rocky areas and border zone, pile all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. Protect pond area between T/5 & T/6 with 300′ buffer from edge of pond or riparian vegetation, whichever is greater. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat.
T/8+ – T/15	Clear, crush, pile and burn an area approximately six acres (200 feet by 1320 feet) within the transmission line right-of-way between the Helms switchyard and Courtright Road. This area is a deer migration corridor. Clearing and burning will stimulate the production of favorable forage species.	T/7 – T/9 Mechanically clear ROW except in rocky areas. Manually remove trees in rocky areas and create brush piles with resulting debris for habitat. Between T8 & T9 is Jim Meadow Mitigation Area – No mechanical clearing in the meadow – trees here are to be removed manually. Lost Canyon at T6 – T7. T/9 – T/15 Manually remove conifers. Limb all resulting logs and pile in windrows. All limbs can be mechanically mulched or chipped on site or lopped and scattered. Streamside buffers of 300′ on each side of the stream, measured from bankfull edge of the stream, will apply between the following groups of towers: T/8 – T/9, T/15 – T/16 (Shorthair Creek). No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. Within streamside buffers trees that must be removed will be removed manually. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat.

Table 1. (continued)

Location	1978 wildlife habitat plan direction	2004 vegetation management prescriptions
		T/15 – T/18 Manually remove trees and create brush piles with resulting debris for habitat. Between T/17 & T/18 leave roadside screening along Courtright Rd. remove trees over 10′ tall or top to 10′ tall if shorter trees and brush are not present.
		T/18 – T/27 Manually remove trees, create brush piles with resulting debris for habitat, OR mechanically clear a 20′ wide meandering path from tree to tree. If between T/23 & T/27 is too steep (generally > 50 percent) to mechanically clear, manually remove trees and pile resulting debris where brush is absent; otherwise lop and scatter. Deer migration corridor at T/19 – T/20 leave roadside screening along road. Between T/27 – T/28 leave brush along road 10S16C.
		T/28 (between tower a & b): Meadow area will require buffer zone that is 300′ from edge of the meadow or riparian vegetation, whichever is greater. Leave brush species intact for wildlife habitat, cover, and edge effect. For trees within the meadow and the buffer zone, manually remove conifers over 5′ in height. Pile resulting debris for habitat. No mechanical clearing within buffer zone.
		T/28 – T/30 Mechanically clear wire zone except in rocky areas. Manually remove trees in rocky areas and border zone and create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife.
		T/30 – T/32 PG&E Parcel & wildlife mitigation area. This area has special requirements under the Helms FERC License. Consult with the North Kings Wildlife Management Team. Future work will include danger tree removal and selective herbicide applications.
		T/32 – T/33 Long Meadow Creek will require a 300′ buffer on each side of the stream, measured from bankfull edge of the stream. Manually remove trees and create brush piles with resulting debris for habitat. No mechanical clearing within buffer zone.
		T/33 – T/36 Manually remove trees, resulting debris will either be chipped and removed or piled for habitat. Locations for chipping and/or piling will be carefully selected and all access will be limited to existing roads to avoid impact to the watch list species (Yosemite ivesia, Ivesia unguiculata). Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife.
		T/36 – west of T/38 Archaeology sensitive area. Flag and avoid ground disturbing activities. Manually remove trees, resulting debris will be lopped and scattered or piled for habitat.
		West of T/38 – west of T/40 Manually remove trees, resulting debris will either be chipped and removed or piled for habitat. Locations for chipping and/or piling will be carefully selected and all access will be limited to existing roads to avoid impact to the watch list species (Yosemite ivesia, Ivesia unguiculata). Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. Between T/39 – T/40 leave buffer along road 10S70.
		West of T/40 – east of T/41 McKinley Grove Road crossing. Manually remove only those trees within 35′ of the conductors.
		East of T/41 – west of T/45 Mechanically clear wire zone except in rocky areas. Manually remove trees in rocky areas and border zone and create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife.
T/46 – T/47+	Meadow No. 2 Remove most lodgepoles from meadow proper – girdled large trees. Plant willows along two drains which flow from south to north, also fence plantings along creeks to protect willows until successful establishment. Recommend planting elderberry and bittercherry.	w/o T/45 – T/50 Manually remove trees and create brush piles with resulting debris for habitat. Streams (Tributaries to East Fork Deer Creek) between T/46 – T/47 and T/49 – T/50 will require a 300′ buffer on each side of the stream, measured from bankfull edge of the stream Meadow #5 is just west of T/50. Meadows will also require buffer zones that are 300′ from edge of the meadow or riparian vegetation, whichever is greater. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat.

Table 1. (continued)

Location	1978 wildlife habitat plan direction	2004 vegetation management prescriptions
T/58+ – west of T/68+	Clear, crush, pile and burn an area approximately 48 acres within the transmission line right of way *48 acres total outside of the right-of-way on both sides of Bull Creek with the exception of the first 200 feet east of Bull Creek and 280 feet west of Bull Creek and the first 200 feet on both sides of Deer Creek. Preserve brush and oak species within the area during the clearing operation. Prepare seed bed, drill and/or hand seed, plant herbaceous species and fertilize the cleared portion; such activities are subject to the steepness of terrain, existing vegetation, and erosion potential of the area. Maintain 60 percent of the cleared portion in herbaceous species unless otherwise agreed. Seeding herbaceous species will increase available forage improve quality of forage and assist in delaying and spreading deer over a larger region within the holding area.	T/50 – T/64 Manually remove trees and create brush piles with resulting debris for habitat, OR mechanically clear a variable width path 20–40′ wide meandering path from tree to tree. Stream between T/59 – T/60 requires buffer zone that is based on the current Forest Service Standard & Guidelines for streams. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. T/64 – T/65 Bull Creek requires buffer zone that is zones that are 300′ from edge of the meadow or riparian vegetation, whichever is greater. Manually remove danger trees and pile resulting debris for habitat. No mechanical clearing within buffer zone. T/65 – w/o T/75 Due to steep slopes, manually remove trees in rocky areas and border zone and create brush piles with all resulting debris for habitat or lop and scatter all resulting debris. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. Stream (Tributary to Deer Creek) between T66 – T67 requires a buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat.
		w/o T/75 – e/o T/76: Dinkey Creek requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove hazard trees and create brush piles with resulting debris for habitat. Manually remove trees and pile brush for habitat. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. T/76 – T/77 Due to steep slopes manually remove trees and create brush piles with resulting debris for habitat or lop and scatter all resulting debis. T/77 – T/85 Mechanically clear wire zone except in rocky areas. Manually remove trees in rocky areas and border zone and create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. 10S24 Ross Crossing Road (road 10S24) near 10S67 where road crosses under T/L (near T/77 – T/79). Leave buffer strip of existing cedars near road as roadside screening; remove trees over 10′ in height or top to 10′ tall if shorter trees and brush are not present. T/80 – T/81 Tributary to Dinkey Creek requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove danger trees and create brush piles with resulting debris for habitat. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. w/o T/85 – e/o T/86 Oak Flat Creek requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove danger trees and create brush piles with resulting debris for habitat. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat.
T/86 – T/99	Plant black oak trees along existing fuel break east of Fence Meadow Lookout, in an area of approximately 29 acres (200 feet by 6,200 feet). The number of oak trees permitted to within this area will follow current "shaded fuel break" policy of the Sierra National Forest. Black oaks produce acorns which are a staple for many wildlife species. Planting sites for oak trees will be carefully selected to avoid future interference with the safe operation of the transmission line.	e/o T/86 – w/o T/87 Manually remove trees and create brush piles with resulting debris for habitat. w/o T/87 – e/o T/89 Bear Meadow Creek (T87 – T88) requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove trees and create brush piles for habitat. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. T/89 – T/99 Mechanically clear ROW in a brush patch arrangement. In areas where oak trees provide the only deer sheltering habitat, small oaks will be retained until sufficient cover for deer sheltering is established.

Table 1. (continued)

Location	1978 wildlife habitat plan direction	2004 vegetation management prescriptions
Milepost 14 to 20	Particular attention will be made in the clearing operations to leave shrubs and forbs along the perimeter of the corridor to establish proper "edge effect" for wildlife. Slash piles (brush piles) created by clearing operations should be left in designated areas to improve habitat for small game and non-game species. These brush piles will be arranged so as not to conflict with safe and efficient operation of the transmission line.	T99 – T106. Manually remove trees in the ROW, lop and scatter resulting debris.
T/102 – T/107	Broadcast burn slash and seed with perennial grasses and forbs, a 27 acre area west of Fence Meadow Ridge. *An additional 100 – foot strip on each side of the complete clearing outside the right-of-way will be partially converted to grass. The total corridor width for vegetative manipulation will be 320 feet. Only about 20 percent of the 27 acres will require manipulation. Retain black oak, canyon oak and blue oak trees, where safe operation of the transmission line so permits. Prepare seed bed, drill, plant herbaceous species and fertilize the cleared area. Several applications of an approved herbicide will be necessary to maintain a grass cover. This area is within the Haslett Basin Key Winter Range. The type conversion will result in an interspersion of vegetative types and offer greater forage variety to wildlife, particularly deer.	
		e/o T/107 – T/110 Mechanically clear and masticate trees and brush in ROW except in rocky areas. Manually remove trees in rocky areas and masticate resulting debris. T107 – T109 streams require buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove danger trees and create brush piles with resulting debris for habitat. No mechanical clearing within buffer zone – manually remove trees, pile all resulting debris for habitat. e/o T110 – w/o T112 Private Property. Future work will include danger tree removal and selective herbicide applications. e/o T113 – w/o T/118 USFS Property. Mechanically clear and masticate trees and brush in wire zone except in rocky areas. Manually remove trees in rocky areas and masticate resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. w/o T/118 – e/o T/119 USFS Property. Big Creek requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove danger trees and lop and scatter resulting debris. No mechanical clearing within buffer zone. Road 10S04 leave buffer along road edge. e/o T/119 – w/o T/121 USFS Property. Manually remove trees in wire zone and lop and scatter resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. Maintain roadside screening at road crossing, road 10S04.
T/121+ – T/129	Subject to the terrain, existing vegetation and conductor clearances: pile and burn slash and seed with perennial grasses and forbs an area of approximately 19 acres between Rush Creek and Deep Creek.	e/o T/121 – w/o T/122 Private Property. Future work will include danger tree removal and selective herbicide applications. e/o T/123 – w/o T/126 USFS Property. Mechanically clear and masticate trees and brush in wire zone except in rocky areas. Manually remove trees in rocky areas and masticate resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife.

Table 1. (continued)

Location	1978 wildlife habitat plan direction	2004 vegetation management prescriptions
	*An additional 100 foot strip on each side of the complete clearing will be partially converted to grass. The total corridor width for vegetative manipulation will be 320 feet. In areas of 45 percent slope of less, the cleared area will be 320 feet wide by 200 feet long. A leave-strip consisting of existing vegetation 20 feet wide will be left between clearings. On slopes greater than 45 percent, clearings should be 100 feet long by 320 feet wide. Leave strips should be 20 feet wide. Following this clearing prescription, approximately 15 acres will be cleared. A mosaic clearing pattern will result and leave strips will minimize erosion potential. Prepare seed bed, drill, plant herbaceous species and fertilize the cleared portion. Clearing and converting brush to grass will offer plant species diversity and improve forage quantity and quality. Several applications of an approved herbicide will be necessary to maintain a grass cover.	w/o T/126 – w/o T/127 Private Property. Future work will include danger tree removal and selective herbicide applications. w/o T/127 – w/o T/128 USFS Property. Manually remove trees in wire zone and lop and scatter resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. No mechanical clearing on USFS property within 0.6 km of perennial pond near Deep Creek. w/o T/128 – w/o T/131 Private Property. Future work will include danger tree removal and selective herbicide applications.
		w/o T/131 – w/o T/132 USFS Property. Mechanically clear and masticate trees and brush in wire zone except in rocky areas. Manually remove trees in rocky areas and masticate resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. Stream requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove hazard trees and lop and scatter resulting debris. No mechanical clearing within buffer zones.
T/133+ – T/138+	Broadcast burn slash and seed with perennial grasses and forbs, an eight acre area southeast of Bob's flat. *An additional 100-foot strip on each side of the complete clearing will be partially converted to grass. The total corridor width for vegetative manipulation will be 320 feet. Prepare seed bed, drill, plant herbaceous species and fertilize the cleared area. Several applications of an approved herbicide will be necessary to maintain a grass cover.	e/o T/133 – w/o T/136 Private Property. Future work will include danger tree removal and selective herbicide applications. T136 – T137 USFS Property. Stream requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. Manually remove hazard trees and lop and scatter resulting debris. No mechanical clearing on USFS property within 0.6 km of seasonal pond near tower 137. e/o T/137 – w/o T/138 USFS Property. Manually remove trees and brush in wire zone and lop and scatter resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. No mechanical clearing on USFS property within 0.6 km of seasonal pond near tower 137.
		w/o T/137 – w/o T/139 Private Property. Future work will include danger tree removal and selective herbicide applications. w/o T/139 – e/o T/139 USFS Manually remove trees and brush in wire zone and lop and scatter resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. No mechanical clearing on USFS property within 0.6 km of seasonal pond near tower 137. e/o T/139 – e/o T/142 Private Property. Future work will include danger tree removal and selective herbicide applications. e/o T/142 – w/o T/144 USFS Property. Manually remove trees and brush in wire zone and lop and scatter resulting debris. Manually remove trees in rocky areas and border zone, create brush piles with all resulting debris for habitat. Where they exist leave shrubs and forbs in the border zone to establish proper "edge effect" for wildlife. T/144 – T/145 stream requires buffer zone that is 300′ on each side of the stream, measured from bankfull edge of the stream. No mechanical clearing within buffer zone – manually remove trees, pile allresulting debris for habitat. T145 - All Private Property. Future work will include danger tree removal and selective herbicide applications.

the EA. Threatened, endangered, and sensitive species surveys were conducted as were cultural surveys. The results of the surveys necessitated changes to the vegetation plan in order to protect identified resources.

STATUS

The first draft of the EA was submitted in June of 2003, a year after the vegetation management plan was completed. USFS comments on the first draft were received back in October of 2003. However, it was at this point that a major issue was raised since the first draft had been prepared without recognition of the issues associate with the aquatic buffers. This issue evolved into an even more serious issue when the USFS Hydrologist pointed out that the buffers in the Sierra Nevada Framework would effectively preclude all our proposed activities from occurring. Although this resulted in a fairly substantial delay while a new approach was developed and the document revised, it pointed out that our collaboration was successful and the team was truly working together towards a common goal. This new approach included the development of two separate tables to address herbicide buffers and aquatic features (Tables 2 and 3). The changes were made to the EA and it was resubmitted in May of 2004. Although there were only minor revisions to the document at this point, not all of the specialists were readily available and the last revisions were received in August of 2004. As mentioned, these were relatively minor revisions to be incorporated, and the final draft of the EA was submitted later that same month.

The Legal Notice is due to be published September of 2004. During the public scoping period an implementation plan will be developed. Once the comment period closes any comments will be addressed and the responses submitted back to the SNF. Once the USFS decision is published, there may be an appeal period if any of the commenters are determined to have

Table 2. Herbicide buffers on perennial streams, inner gorges and special aquatic features

Herbicide	Buffers for Perennial Streams, Inner Gorges,[1] and Special Aquatic Features (wetlands, ponds, lakes, meadows, bogs, vernal pools, springs)			
	Treatment Method/Activity			
	Cut Stump, Hack & Squirt, Injection	Foliar for Noxious Weed Control[2]	Foliar (other than Noxious Weed Control), basal stem, and soil applications	Mixing, Loading, Cleaning
Garlon 3A, Stalker, Arsenal, Chopper, Accord, Rodeo	25 feet[3]	25 feet	300 feet/top of inner gorge	300 feet/top of inner gorge
Garlon 4, Hexazinone	300 feet/top of inner gorge	300 feet/top of inner gorge	300 feet/top of inner gorge	300 feet/top of inner gorge

[1]Defined by stream adjacent slopes greater than 70 percent.

[2]Noxious weed control only using ultra low volume (ULV) nozzles with orifice size and spray pressure set to produce droplets as a minimum of 150 microns, nozzle heights at the lowest possible height, and cross-wind speed of less than five mph.

[3]Except for Bear Meadow Creek and Oak Flat Creek where buffer distance will be reduced to 5 feet to control oaks from resprouting.

Table 3. Herbicide buffers on seasonal streams

Herbicide	Buffers for Seasonally Flowing Streams (includes ephemerals with defined channel or evidence of scour)			
	Treatment Method/Activity			
	Cut Stump, Hack & Squirt, Injection	Foliar for Noxious Weed Control[1]	Foliar (other than Noxious Weed Control), basal stem, and soil applications	Mixing, Loading, Cleaning
Garlon 3A, Stalker, Arsenal, Chopper, Accord, Rodeo	5 feet	5 feet	150 feet when water present; On Stream Value Class[2] II & III, 50 feet when dry. On Class IV streams, 5 feet when dry.	150 feet
Garlon 4, Hexazinone	150 feet	150 feet	150 feet	150 feet

[1]Noxious weed control only using ultra low volume (ULV) nozzles with orifice size and spray pressure set to produce droplets as a minimum of 150 microns, nozzle heights at the lowest possible height, and cross-wind speed of less than five mph.

[2]Stream Value Classes I-V are defined by the Soil and Water Conservation Practices Handbook, August 1989, Sierra National Forest Supplement No. 1. These classes are commonly utilized categories on the Sierra National Forest. Stream Classifications shall be identified, mapped and approved by the Forest Hydrologist prior to operations.

standing. Although no comments were received after the initial scoping, it is likely that comments will be received during this scoping. Even if any of the comments are substantive, the project team and associated resources will be able to adequately address any concerns. One difference between this project and many of the USFS projects that are appealed is that this project does not have a date after which it is no longer viable. Many of the environmental groups that comment seek to delay projects until they are no longer viable for the USFS to complete. The intention is to implement the EA beginning in 2005.

CONCLUSIONS

Successfully negotiating the NEPA process requires excellent interpersonal skills as well and a thorough understanding of all of the issues, both past and present. It requires a willingness to become educated about unfamiliar issues, and the ability to think outside of the box. And last, but not least, adequate funding and abundant patience are necessities.

REFERENCES

Garcia and Associates (GANDA). 2001a. Northern Goshawk Surveys and Habitat assessment for Amphibians and Aquatic Reptiles, Helms-Gregg 230 kV Transmission Line Vegetation Management Project. Report prepared for PG&E Technical and Ecological Services. San Anselmo, California. December, 2001.

Garcia and Associates (GANDA). 2001b. Protocol Surveys for the California Red-legged Frog, Vegetation Management of the Helms-Gregg 230 kV Transmission Line. Report prepared for PG&E Technical and Ecological Services. San Anselmo, California. November, 2001.

Garcia and Associates (GANDA). 2004. Riparian Conservation Objective Analysis, Vegetation Management of the Helms-Gregg 230 kV Transmission Line. Report prepared for PG&E Technical and Ecological Services. San Anselmo, California. April, 2004.

Norris, L.A. 1999. ROW on federal lands and NEPA. UAA Quarterly, winter 1999. Vol 8. No. 2. pp. 1–5.

Pacific Gas and Electric Company (PG&E). 1978. Helms Pumped Storage Project Wildlife Habitat Plan. Exhibit S of the Helms Pumped Storage License Application to the Federal Energy Regulatory Commission. February 1978.

Pacific Gas and Electric Company (PG&E). 2002. Heritage Resources Report prepared for Helms-Gregg Transmission Lines. Glenn Caruso, Senior Cultural Resource Specialist, Pacific Gas & Electric Company, 245 Market Street, S.F.

Pacific Gas and Electric Company (PG&E). 2003a. Valley Elderberry Longhorn Beetle Conservation Program. Pacific Gas and Electric Company and U.S. Fish and Wildlife Service. March 2003. 41 pp.

Pacific Gas and Electric Company (PG&E). 2004. Vegetation Management Plan for the Helms Gregg 230 kV Transmission Line on the Sierra Nevada Forest. Pacific Gas and Electric Company. Auburn, Ca. 2003.

Pacific Gas and Electric Company (PG&E) and Garcia and Associates (GANDA). 2003. Biological Evaluation/Biological Assessment: Integrated Vegetation Management for Pacific Gas and Electric Company's Helms-Gregg 230 kV Transmission Line. San Ramon, California. October 2003.

Pacific Gas and Electric Company (PG&E) and Garcia and Associates (GANDA). 2004. Environmental Assessment: Integrated Vegetation Management for Pacific Gas and Electric Company's Helms-Gregg 230 kV Transmission Line. San Ramon, California. September 2004.

Stebbins. 2002. Botanical Resources Survey Report prepared for the Helms-Gregg Transmission Line Project. John Stebbins, Botanist, 357 Adler Avenue, Clovis, CA.

Syracuse Environmental Research Associates (SERA). 2002. Neurotoxicity, Immunotoxicity, and Endocrine Disruption with Specific Commentary on Glyphosate, Triclopyr, and Hexazinone: Final Report. Syracuse Environmental Research Associates, Inc. Fayetteville, New York. SERA TR 01-43-08-04a, 2002.

Syracuse Environmental Research Associates (SERA). 1996a. Selected commercial formulations of glyphosate – Accord, Rodeo, Roundup and Roundup Pro risk assessment, Final Report. Prepared for USDA Forest Service by Syracuse Environmental Research Associates, Inc. Syracuse, New York. Report number SEAR TR 96-22-02-01c.

Syracuse Environmental Research Associates (SERA). 1996b. Selected commercial formulations of triclopyr – Garlon 3A and Garlon 4 risk assessment, Final Report. Prepared for USDA Forest Service by Syracuse Environmental Research Associates, Inc. Syracuse, New York. Report number SEAR TR 96-22-02-02a.

Syracuse Environmental Research Associates (SERA). 1997. Selected commercial formulations of hexazinone human health and ecological risk assessment, Final Draft. Prepared for USDA Forest Service by Syracuse Environmental Research Associates, Inc. Syracuse, New York. Report number SEAR TR 96-21-04-01b.

Syracuse Environmental Research Associates (SERA). 1999. Imazapyr (Arsenal, Chopper and Stalker Formulations) Final Report. Task Nos 14. USDA/USFS contract No 53-3187-5-12, 43-3187-8-0222. Prepared by Syracuse Environmental Research Associates, Inc. for USDA Forest Service. May 6, 1999.

USDA Forest ServicePacific Southwest Region. 2004. Sierra Nevada Forest Plan Amendment. Final Supplemental Environmental Impact Statement. USDA Forest Service, Pacific Southwest Region, Vallejo, CA. January 2004. 492 pp.

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Afforestation on Power Line Rights-of-Way Using Speckled Alder (*Alnus rugosa*)

Edward J. Glover and Robert F. Young

Many energy-generating utilities in the United States and Canada are investing heavily in forest carbon management, specifically carbon sequestration projects, to offset emissions of greenhouse gases. The simplest of these projects involves planting trees to create forest carbon sinks. In Canada, the driving force behind such activity is the ratification of the Kyoto Protocol requiring greenhouse gas emissions to be reduced to 6 percent below 1990 levels by 2012. Nova Scotia Power Inc. has been actively planting shrub seedlings on power line rights-of-way since 1994 to establish sustainable compatible vegetative communities. The vast majority of the seedlings used for this purpose are speckled alder (*Alnus rugosa*). As the company is committed to exploring options to offset greenhouse gas emissions, the opportunities related to speckled alder plantations as a forest carbon management project are being reviewed. In 2003, a three-year project between NSPI and the Canadian Forest Service was initiated to explore and develop partnership arrangements for promoting forest carbon management on private lands and power line rights-of-way. The company will undertake the afforestation of 375 ha of power line rights-of-way by planting speckled alder. Initial results indicate that the potential for speckled alder to sequester carbon is substantial.

Keywords: Kyoto, forest carbon management, speckled alder, power line rights-of-way, Nova Scotia Power Inc., right-of-way

INTRODUCTION

Since 1994, Nova Scotia Power Inc. (NSPI) has been planting shrubs to establish stable vegetative communities on power line rights-of-way. Through site occupancy, the shrub plantations would eventually control the establishment of taller tree species. In 1998, NSPI adopted a strategy for the creation of sustainable power line rights-of-way and recognized planting as an integral part of that effort. The company's plan is to increase right-of-way sustainability by 10 and 15 percent on the transmission and distribution systems respectively through incremental increases annually. To meet these targets, the company is involved with planting hundreds of thousands of compatible species on approximately 1,650 ha of transmission and 424 ha of distribution rights-of-way. The vast majority of this effort involves the planting of speckled alder (*Alnus rugosa*) seedlings.

Canada, by ratifying the Kyoto Protocol, has made an international commitment to reduce greenhouse gas emissions to levels 6 percent lower than those of 1990 by the year 2012. One jurisdiction under scrutiny for contributing to overall emissions is the electricity generation sector. Electricity generation accounted for 16 percent of direct emissions in 1997 and is projected to increase to 22 percent by 2010 (NSPI Business Plan, 2000). Electric utilities burning fossil fuels for energy generation present the greatest potential for reductions through changes in technology and fuel choices. As such, the sector will play an integral role in Canada's national climate change strategy. As the ratification of Kyoto preceded the finalization of an implementation plan, industry awaits firm policy and program decisions from the government of Canada. In the interim, NSPI has set targets for significant reductions in overall emissions of several pollutants (i.e. sulphur dioxide, nitrogen oxides) between 2005 and 2010. These re-

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ductions will be achieved in the short term by using cleaner fuels, such as natural gas and higher quality coals, and by introducing more renewable forms of energy generation, such as wind power. While these initiatives are directly in response to overall emissions targets, they are anticipated to result in some greenhouse gas emission improvement at NSPI.

Although most greenhouse gas reductions in the utility industry are predicted to come from new generation capacity using "cleaner" energy sources, there is some certainty that energy efficiency and alternative fuels will not provide sufficient reductions in carbon dioxide to impact climate change. Although specific required targets remain unclear, NSPI, like most utilities have initiated significant efforts to better understand all the available options for mitigating greenhouse gas emissions. As such, this paper explores the potential for investing in an area typified by the forestry sector known as afforestation and the establishment of carbon sinks through planting.

Forest Carbon Management Partnership

In 2003, a 3-year Forest Carbon Management Partnership between NSPI and the Canadian Forest Service (CFS) was initiated to explore and develop arrangements for the following:

- The promotion of afforestation on power line rights-of-way and private lands;
- Developing protocols for the acquisition and trading of carbon credits;
- The coordination of research and data collection opportunities; and
- Undertaking the afforestation of 350 ha of transmission right of way and 25 ha of distribution right-of-way.

The partnership is one of only five initiated in Canada as part of the Feasibility Assessment of Afforestation for Carbon Sequestration (FAACS). The most prominent activity associated with the partnership involves a planting program for both; on rights-of-way with speckled alder, and on private lands adjacent to rights-of-way with spruce (*Picea sp.*). A process for identifying lands that qualify as afforestation activities under Kyoto Article 3.3 will be developed and the potential these projects have for carbon sequestration will be quantified.

As with all afforestation projects, the requirements for certification, monitoring and verification have yet to be finalized. While afforestation using fast growing tree species has been accepted as carbon offset projects under Kyoto, it is currently somewhat unclear whether or not planting speckled alder qualifies. While plant biomass is the most understood form of a carbon sink, the rules for the inclusion of planting speckled alder are undecided. There is indication that linear projects such as power lines and road corridors will be denied. As well, plantations less than 1 hectare in size may also be considered insignificant and fail to be recognized. The fact that speckled alder is being planted for the eventual reduction in herbicide use, however, may aid in its validation. Negotiations through NSPI's partnership with the CFS will assist in having speckled alder plantations be viewed by the Canadian Government as a viable option for storing carbon.

The advantage is in NSPI's favour as planting is already an integral part of the vegetation management program. In addition to being viewed as a progressive approach for vegetation control, it is possible to align planting with public awareness initiatives around the company's efforts to meet emissions reductions and the general understanding of the Kyoto Protocol.

Afforestation projects

Planting projects are being established in 2 distinctly different land use types: 1) power line rights-of-way (on-ROW) and, 2) private lands adjacent to rights-of-way (off-ROW).

The sites chosen for on-ROW were part of an ongoing vegetation management program assuming the use of herbicides every 7 years. Site preparation was therefore in the form of a herbicide application. The off-ROW projects include old fields (i.e. abandoned farmland) that were suitable for planting. This best characterizes the requirements of afforestation and the necessity to establish trees where they have not been historically grown to support woodlands management. If necessary, site preparation on the fields will be implemented through mechanical means.

All plantations were established at a spacing of 2.1 m × 2.1 m or 2400 stems ha^{-1}. Based on these assumptions, biomass equations were adopted from Smith and Brand (1983) to quantify the baseline for carbon content of on-ROW and off-ROW project areas (Appendix I).

Project baseline

A project baseline is used as a reference point to calculate additional carbon sequestered due to project activities. This baseline is measured as the change in carbon stock expected without the project activity. This method was chosen primarily for two reasons: 1) very well suited to quantify carbon stocks for afforestation projects; 2) current direction for afforestation/reforestation baseline for Clean Development Mechanism projects (Article 12 of the Kyoto Protocol).

Carbon emissions/removals in baseline scenario

Carbon emissions/removals for on-ROW projects

The baseline carbon stock for on-ROW projects is quantified as the average carbon stored over a 7-year cycle (Appendix II). A site at the start of a 7-year cycle, subsequent to herbicide application, will be characterized primarily by grassland (family Gramineae). The estimated aboveground carbon for grassland at 100% cover is 0.605 Tons Carbon per Hectare (tC ha^{-1}). The

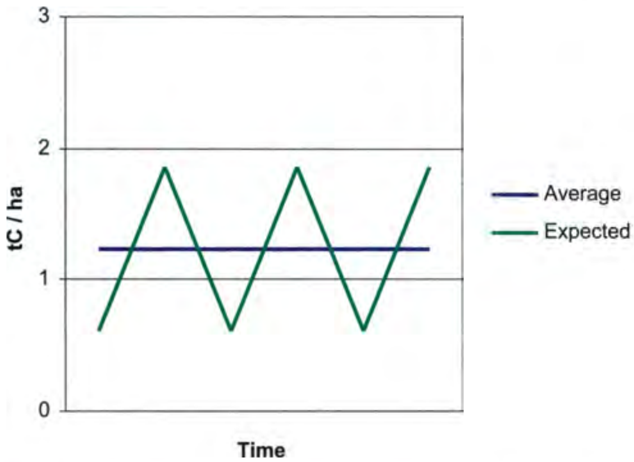

Fig. 1. Expected and average amounts of carbon stored on transmission line corridors.

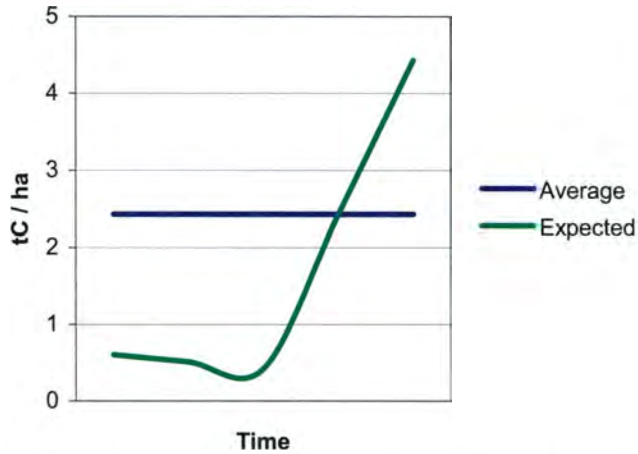

Fig. 2. Expected and average amounts of carbon stored on abandoned farmland.

vegetation condition at the end of the 7-year cycle was quantified from a network of permanent sample plots established on transmission line corridors by NSPI in 1999. Maple and birch were the most prevalent species at an average of 1455 stems ha^{-1} and 5 cm in diameter. This intolerant hardwood vegetative condition at the end of the 7-year cycle amounted to 1.857 tC ha^{-1}of carbon stored. The average amount of carbon stored within the vegetation management 7-year cycle was 1.231 tC ha^{-1} (Fig. 1).

Below-ground carbon will not change significantly over time without any on-ROW project activity because the difference between the loss in soil C following vegetation treatment and the gains in soil C through net primary production with vegetation regeneration is negligible.

Carbon emissions/removals for off-ROW projects

The baseline carbon stock for off-ROW projects was calculated based on the typical plant communities that might occupy inactive agricultural land (Appendix III). Common seral stages of abandoned farmland are a sequence of: herb-shrub-hardwood trees. The estimated carbon stored in a herb community is 0.605 tC ha^{-1}; a shrub community (based on Rosa spp.) is 0.240 tC ha^{-1}; and intolerant hardwoods is 4.434 tC ha^{-1}. The average amount of above ground carbon stored on abandoned farmland is 2.428 tC ha^{-1} (Fig. 2).

A number of factors need consideration for quantifying soil carbon for the off-ROW project baseline. The amount and rate soil carbon is being stored is in part a function of: previous land practices, soil type, climate, and net primary production. Insufficient data at this time does not warrant an estimate of soil carbon for an off-ROW baseline.

General methodology for estimating carbon emissions/removals

Biomass refers to the total weight of organic material (Kimmins, 1997). Approximately 50% of biomass is carbon (Freedman et al., 1992). The on-ROW project carbon stock was estimated based on diameter data from existing alder plantations. The off-ROW project carbon stock was based on average diameter growth for red spruce over 10 years (Appendix III).

Calculations of carbon emissions/removals in the project scenario

Emissions for on-ROW and off-ROW projects

The largest amount of emissions for on-ROW and off-ROW project activities was from site preparation. Herbicide manufacturing and application produce average carbon emissions of 20.7 and 0.7 Kg C ha^{-1} year^{-1} respectively (Stinson, 1999). Moldboard plowing produces an estimated 12.6 Kg C ha^{-1} year^{-1} as does the operation and repair of machinery (Stinson, 1999).

Vegetative removals for on-ROW projects

On-ROW projects involved the planting of speckled alder (*Alnus rugosa*) on corridor not directly under conductor and offset from structures. Farrar (1995) describes speckled alder as small trees or tall shrubs that can grow up to 8 m high and 12 cm in diameter. Planted at a density of 2400 stems ha^{-1}, it's estimated that vegetative reproduction will increase plantation density to 3100 stems ha^{-1} and 7 cm in diameter during the first 15 years. At 20 years, the number of stems is estimated to reduce from intraspecific competition to 2900 stems ha^{-1} at 8 cm in diameter. Based on this expected 20 year growth and development trend (Table 1) (Fig. 3) alder have the potential to store 13.76 tC ha^{-1}(Appendix IV).

Vegetative removals for off-ROW projects

Off-ROW projects were planted with spruce at a density of 2400 stems ha^{-1}. An average 10-year growth in diameter of 3.3 cm (Burns and Honkala, 1990) was used to calculate total biomass and estimate the carbon storage capacity (Appendix V). Table 2 shows that a 20-year old spruce plantation at 2.1 m spacing will sequester 5.91 tC ha^{-1}.

Table 1. Vegetation carbon pool for on-ROW plantation projects

Species	Age	Density (stems ha^{-1})	Diameter (cm)	Total biomass (t ha^{-1})	Above and below ground carbon (tC ha^{-1})
Speckled Alder	5	2400	3	1.99	0.796
	10	3000	6	21.74	6.521
	15	3100	7	39.62	10.236
	20	2900	8	64.51	13.755

Fig. 3. Eight-year-old speckled alder plantation located on a transmission line corridor in Nova Scotia.

Table 2. Vegetation carbon pool for off-ROW plantation projects

Species	Age	Density (stems ha^{-1})	Diameter (cm)	Total biomass (t ha^{-1})	Above and below ground carbon (tC ha^{-1})
Spruce	5	2400	1.65	0.496	0.248
	10	2400	3.3	2.421	1.21
	15	2400	4.95	6.12	3.06
	20	2400	6.6	11.815	5.91

Soil removals for on-ROW and off-ROW projects

Presently, there is very little information in Nova Scotia on the dynamics of below-ground carbon due to land use change. Soil carbon is important to consider; it's estimated that over half of total carbon in boreal forest ecosystems is stored in the soil (Stinson, 1999). Generally, changes in soil C is the net difference between plant materials and roots being input into the soil and soil respiration.

Polglase et al. (2000) has summarized 41 international published and unpublished studies from 197 sites on soil C change from afforestation and reforestation activities. Their study expresses the rate of change in soil C, as a weighted average (Eq. 1). Soil carbon was estimated at a sampling depth of <30 cm for plantations <10 years of age to be 1.97 g m^{-2} y^{-1}. For plantations >10 years of age, the soil carbon content rose to 16.2 g m^{-2} y^{-1}.

$$\Sigma(\text{Change in soil C, g m}^{-2})/\Sigma(\text{Age}) \quad (1)$$

For the purposes of this study it is assumed that on-ROW project's characterized by small tree plantations will maintain a rate of change throughout the project duration of 1.97 g m^{-2} y^{-1}, whereas plantations >10 years established off-ROW corridors will see a rise in soil carbon content after 10 years of 16.2 g m^{-2} y^{-1}.

Key uncertainties in project carbon emissions/removals

Estimates of soil carbon sequestration from project activities are general assumptions because explicit data are not available. It's presumed that alder's nitrogen fixing root nodules could enhance sequestering, helping soils achieve full carbon sequestration potential.

Unexpected project disturbance from natural causes (e.g., fire, insect), or from anthropogenic activities (e.g., cutting, spraying) could reduce projected carbon sequestration.

Carbon emissions/reductions during project lifetime

Carbon reductions during on-ROW projects

Net change in carbon for on-ROW projects was calculated as the difference in estimated project carbon sequestration and emissions (Table 3). The project carbon sequestration is a sum of carbon stored in

Table 3. On-ROW project emissions and removals

Project carbon sequestration (tC ha^{-1})	Project carbon emissions (tC ha^{-1})	Net carbon sequestration (tC ha^{-1})
17.695	1.265	16.43

Table 4. Off-ROW project emissions and removals

Project carbon sequestration (tC ha^{-1})	Project carbon emissions (tC ha^{-1})	Net carbon sequestration (tC ha^{-1})
7.73	2.45	5.28

Carbon Reductions for on-ROW projects within the Integrated Vegetation Management Program and FCMP.

alder vegetative biomass (13.755 tC ha^{-1}) and soils over 20 years (3.94 tC ha^{-1}). The project baseline (1.231 tC ha^{-1}) and emissions from the application of herbicides (0.034 tC ha^{-1}) are combined to quantify carbon emissions. The net carbon sequestration from on-ROW project activities was estimated to be 16.43 tC ha^{-1}.

Carbon reductions during off-ROW projects

Determining the net change in carbon for off-ROW projects (Table 4) was based on the sequestration estimated from spruce vegetative biomass (5.91 tC ha^{-1}) and soils (1.82 tC ha^{-1}) versus baseline vegetative storage (2.43 tC ha^{-1}) and site preparation by plow (0.025 tC ha^{-1}). The estimated net carbon sequestration from off-ROW project activities was 5.28 tC ha^{-1}.

NSPI has been planting alders since 1994 as part of an overall program for creating sustainable rights-of-way. The Forest Carbon Management Partnership (FCMP) makes up a portion of that initiative. An analysis of the potential carbon reduction potential for the entire planting effort shows that as much as 40,267.07 tC ha^{-1} (Table 5) can be stored in alder plantations established by NSPI.

CONCLUSION

Based on an expected 20-year growth and development trend, speckled alder plantations on rights-of-way have the potential to sequester more than three times that of spruce of the same age. This is attributed to the morphology of the species as it grows rapidly from establishment and forms numerous stems.

Whether planting speckled alder on rights-of-way is considered part of the emissions reductions solution through carbon offset remains to be determined. It is important to note; however, that the benefits of right-of-way planting projects offer opportunity beyond that specific purpose. Planting speckled alder on power line rights-of-way is associated with many positive attributes: 1) has good public appeal as it demonstrates the utilities physical contribution to the environment, 2) is beneficial to many wildlife species through the provision of food and habitat, 3) will eventually reduce herbicide use on the right-of-way lowering overall management costs, and 4) provides company alignment with the requirements of the Kyoto Protocol.

It is possible that, at some point, consumer's brand NSPI based on the position they take for climate change and continuing a program that is already well established is not a stretch for the utility. If alder plantations do not meet the criteria as a carbon sink, planting still makes economic sense (Young and Glover, 2002). If planting speckled alder does qualify, and considering the extent of NSPI's planting strategy, it is possible that such an effort could accumulate approximately 150,000 carbon dioxide offset credits. At a possible credit worth of $15 each, the plantations have a potential worth of over 2 million dollars (Appendix VI). The activity remains a positive approach and can assist in educating the public on greenhouse gas reduction programs and other emissions targets. As the advantages of planting have already been established within the integrated vegetation management program, the potential for carbon sequestration make the economics that much more suitable.

REFERENCES

Burns, R.M. and B.H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol. 2, 877 p.

Farrar, J.L. 1995. Trees in Canada. Fitzhenry and Whiteside Limited, ON, CAN.

Freedman, B., F. Meth, and C. Hickman. 1992. Temperate Forest as a Carbon-Storage Reservoir for Carbon Dioxide Emitted by Coal-fired Generation Stations. A case study for New Brunswick, Canada. Forest Ecology and Management, 55: 15–29.

Kimmins, J.P. 1997. Forest Ecology: A Foundation for Sustainable Management. Prentice Hall, NJ, USA.

NSPI Business Plan. 2000. Internal Document, Nova Scotia Power Inc. Halifax, Nova Scotia, Canada.

Polglase, P.J., K.I. Paul, P.K. Khamna, J.G. Nyakuenganna, A.M. O'Connell, T.S. Grove, and M. Battaglia. 2000. Change in Soil Carbon Following Afforestation or Reforestation. Retrieved on August 13, 2003 from www.greenhouse.gov.au/ncas.

Table 5. Total potential for on-ROW carbon sequestration within NSPI strategy for planting

Planting program	Transmission (ha)	(tC ha^{-1})	Distribution (ha)	(tC ha^{-1})	Total (tC)
Sustainability	1350	27,109.50	399	6,996.32	34,105.82
FCM Partnership	350	5,750.50	25	410.75	6,161.25
Total Program	1650	32,860.00	424	7,407.07	40,267.07

Stinson, G. 1999. Assessment of Carbon Sequestration in Representative Forests and Agrosystems in Canada. MES Thesis. Dalhousie University. Halifax, Nova Scotia.

Smith, W.B. and G.J. Brand. 1983. Allometric Biomass Equations for 98 Species of Herbs, Shrubs, and Small Trees. Research Note NC-299. North Central Forest Experiment Station. U.S.D.A. Forest Service.

Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verardo, and D.J. Dokken (Eds). 2000. Land Use, Land-Use Change, and Forestry. Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK. Retrieved on June 18, 2003 from http://www.grida.no/climate/ipcc/land_use/271.htm.

Young, R.F. and E.J. Glover. 2002. Planting Shrubs for the Creation of Sustainable Power Line Rights-of-Way. In: Proceedings of the Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Calgary, Alberta. Pp. 97–102.

BIOGRAPHICAL SKETCHES

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Robert F. Young is a Senior Forester with Nova Scotia Power Inc. and holds a BSc in Forestry from the University of New Brunswick. He has been working in the field of vegetation management for over ten years with the majority being with Nova Scotia Power Inc. He is responsible for the development and effective implementation of vegetation management programs for transmission and distribution rights-of-way. He actively participates and serves on committees with organizations including; the Atlantic Vegetation Management Association, the International Society of Arboriculture and the Canadian Institute of Forestry.

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Edward J. Glover holds a degree in Forestry from the University of New Brunswick. Previous work with the company involved the development of a methodology for the implementation of permanent sample plots on speckled alder sites. Mr Glover is currently involved in research on compatible species to further benefit NSPI's planting initiatives.

APPENDIX I

Biomass equation

Calculating Carbon Storage Potential from Biomass Equations

An allometric biomass equation (Eq. 1) was used for estimating biomass in grams ovendry weight from the following biomass regression coefficients (Smith and Brand, 1983).

Species	Coefficients		R2	Independent variable1/	Range of independent variable
	a	b			
Acer rubrum	60.367	2.342	.94	D	0.30–4.10
Alnus rugosa	33.722	2.712	.96	D	0.25–3.00
Betula papyrifera	76.316	2.279	.93	D	1.30–3.60
Gramineae	0.9740	0.6750	.45	PC	–
Picea spp.	65.757	2.287	.97	D	0.50–3.30
Rosa spp.	0.3964	0.7867	.50	PC	–

1/D = basal diameter and PC = Percent Cover

$$Y = aXb \quad (1)$$

where:

Y = predicted biomass (g/1800 cm^2 for PC and g/tree for D)

X = stem diameter or percent cover

a = biomass regression coefficient

b = biomass regression coefficient

Through photosynthesis, atmospheric CO2 is absorbed by plants and stored as carbon.

The proportion of carbon in dry tree biomass is assumed at 50% (Freedman et al., 1992). The mass of carbon stored by vegetation can be estimated using the following formula.

$$C = 0.5 \times Y \quad (2)$$

where:

C = estimated carbon content (g)

0.5 = constant for biomass percent carbon

Y = predicted biomass (g)

APPENDIX II

ON ROW project baseline carbon calculation

Calculations for ON ROW Baseline

$$Y = aXb$$

Start Cycle

Biomass equation coefficients for Gramineae where:

$Y = g/1800\ cm^2$

$X = 100$

$a = 0.9740$

$b = 0.6750$

$$Y = 0.9740 \times 100^{0.6750}$$
$$Y = 0.9740 \times 22.387$$
$$Y = 21.805\ g/1800\ cm^2$$
$$Y = 0.0121\ g\ cm^{-2} \times 100$$
$$Y = 1.21\ t\ ha^{-1} \times 0.5$$
$$Y = 0.606\ tC\ ha^{-1}$$

Grassland baseline average = 0.606 tC ha^{-1}

Assumptions: 100% grassland cover

End Cycle

Biomass equation coefficients for Acer rubrum where:

$Y = g/tree$
$X = 5$
$a = 60.367$
$b = 2.342$

$Y = 60.367 \times 5^{2.342}$
$Y = 60.367 \times 43.349$
$Y = 2116.901\ g/tree$
$Y = 2.117\ kg/tree$
$Y = 2.117 \times 1455\ trees\ ha^{-1}$
$Y = 3080.23\ kg\ ha^{-1}$
$Y = 3.080\ t\ ha^{-1} \times 0.5$
$Y = 1.540\ tC\ ha^{-1}$

Biomass equation coefficients for Betula papyrifera where:

$Y = g/tree$
$X = 5$
$a = 76.316$
$b = 2.279$

$Y = 76.316 \times 5^{2.279}$
$Y = 76.316 \times 39.169$
$Y = 2989.291\ g/tree$
$Y = 2.989\ kg/tree$
$Y = 2.989 \times 1455\ trees\ ha^{-1}$
$Y = 4348.99\ kg\ ha^{-1}$
$Y = 4.349\ t\ ha^{-1} \times 0.5$
$Y = 2.174\ tC\ ha^{-1}$

Intolerant hardwood baseline average = 1.857 tC ha^{-1}
Assumptions:
Trees have 5 cm diameter
Tree density is 1455 stems ha^{-1}

APPENDIX III

OFF ROW project baseline carbon calculation

Calculations for OFF ROW Baseline

$Y = aXb$

Biomass equation coefficients for Gramineae where:

$Y = g/1800\ cm^2$
$X = 100$
$a = 0.9740$
$b = 0.6750$

$Y = 0.9740 \times 100^{0.6750}$
$Y = 0.9740 \times 22.387$
$Y = 21.805\ g/1800\ cm^2$
$Y = 0.0121\ g\ cm^{-2} \times 100$
$Y = 1.21\ t\ ha^{-1} \times 0.5$
$Y = 0.606\ tC\ ha^{-1}$

Grassline average = 0.606 tC ha^{-1}
Assumptions: 100% grassland cover

Biomass equation coefficients for Rosa spp. where:

$Y = g/tree$
$X = 50$
$a = 0.3964$
$b = 0.7867$

$Y = 0.3964 \times 50^{.7867}$
$Y = 0.3964 \times 21.705$
$Y = 8.603\ g/1800\ cm^2$
$Y = 0.0048\ g\ cm^{-2} \times 100$
$Y = 0.48\ t\ ha^{-1} \times 0.5$
$Y = 0.240\ tC\ ha^{-1}$

Biomass equation coefficients for Acer rubrum where:

$Y = g/tree$
$X = 7$
$a = 60.367$
$b = 2.342$

$Y = 60.367 \times 7^{2.342}$
$Y = 60.367 \times 95.328$
$Y = 5754.65\ g/tree$
$Y = 5.754\ kg/tree$
$Y = 5.754 \times 1455\ trees\ ha^{-1}$
$Y = 8373.02\ kg\ ha^{-1}$
$Y = 8.373\ t\ ha^{-1} \times 0.5$
$Y = 4.186\ tC\ ha^{-1}$

Biomass equation coefficients for Betula papyrifera where:

$Y = g/tree$
$X = 7$
$a = 76.316$
$b = 2.279$

$Y = 76.316 \times 7^{2.279}$
$Y = 76.316 \times 84.329$
$Y = 6435.674\ g/tree$
$Y = 6.436\ kg/tree$
$Y = 6.436 \times 1455\ trees\ ha^{-1}$
$Y = 9363.9\ kg\ ha^{-1}$
$Y = 9.364\ t\ ha^{-1} \times 0.5$
$Y = 4.681\ tC\ ha^{-1}$

Intolerant hardwood baseline average = 4.434 tC ha^{-1}
Assumptions: 7 cm tree diameter

APPENDIX IV

ON ROW project estimated vegetation carbon removals

Calculations for ON ROW Project

$Y = aXb$

Biomass equation coefficients for 5 year old Alnus rugosa where:

$Y = g/tree$
$X = 3$
$a = 33.722$
$b = 2.712$

$Y = 33.722 \times 3^{2.712}$
$Y = 33.722 \times 19.677$
$Y = 663.538\ g/tree$

$Y = 0.663$ kg/tree
$Y = 0.663 \times 2400$ trees ha^{-1}
$Y = 1591.2$ kg ha^{-1}
$Y = 1.591$ t ha^{-1} $\times 0.5$
$Y = 0.796$ tC ha^{-1}

Biomass equation coefficients for 10 year old Alnus rugosa where:
$Y = $ g/tree
$X = 6$
$a = 33.722$
$b = 2.712$

$Y = 33.722 \times 6^{2.712}$
$Y = 33.722 \times 128.927$
$Y = 4347.676$ g/tree
$Y = 4.35$ kg/tree
$Y = 4.35 \times 3000$ trees ha^{-1}
$Y = 13{,}043$ kg ha^{-1}
$Y = 13.043$ t ha^{-1} $\times 0.5$
$Y = 6.521$ tC ha^{-1}

Biomass equation coefficients for 15 year old Alnus rugosa where:
$Y = $ g/tree
$X = 7$
$a = 33.722$
$b = 2.712$

$Y = 33.722 \times 7^{2.712}$
$Y = 33.722 \times 195.84$
$Y = 6604.12$ g/tree
$Y = 6.60$ kg/tree
$Y = 6.60 \times 3100$ trees ha^{-1}
$Y = 20{,}460$ kg ha^{-1}
$Y = 20.460$ t ha^{-1} $\times 0.5$
$Y = 10.23$ tC ha^{-1}

Biomass equation coefficients for ***20 year old*** *Alnus rugosa where:*
$Y = $ g/tree
$X = 8$
$a = 33.722$
$b = 2.712$

$Y = 33.722 \times 8^{2.712}$
$Y = 33.722 \times 281.31$
$Y = 9486.33$ g/tree
$Y = 9.48$ kg/tree
$Y = 9.48 \times 2900$ trees ha^{-1}
$Y = 27{,}510$ kg ha^{-1}
$Y = 27.510$ t ha^{-1} $\times 0.5$
$Y = 13.75$ tC ha^{-1}

APPENDIX V

OFF ROW project estimated vegetation carbon removals

Calculations for OFF ROW Project

Biomass equation coefficients for ***5 year old*** *Picea spp. where:*
$Y = $ g/tree
$X = 1.65$
$a = 33.722$
$b = 2.712$

$Y = 65.757 \times 1.65^{2.287}$
$Y = 65.757 \times 3.143$
$Y = 206.694$ g/tree
$Y = 0.207$ kg/tree
$Y = 0.207 \times 2400$ trees ha^{-1}
$Y = 496.06$ kg ha^{-1}
$Y = 0.496$ t ha^{-1} $\times 0.5$
$Y = 0.248$ tC ha^{-1}

Biomass equation coefficients for 10 year old Picea spp. where:
$Y = $ g/tree
$X = 3.30$
$a = 33.722$
$b = 2.712$

$Y = 65.757 \times 3.30^{2.287}$
$Y = 65.757 \times 15.34$
$Y = 1008.75$ g/tree
$Y = 1.008$ kg/tree
$Y = 1.008 \times 2400$ trees ha^{-1}
$Y = 2420.99$ kg ha^{-1}
$Y = 2.421$ t ha^{-1} $\times 0.5$
$Y = 1.21$ tC ha^{-1}

Biomass equation coefficients for 15 year old Picea spp. where:
$Y = $ g/tree
$X = 4.95$
$a = 33.722$
$b = 2.712$

$Y = 65.757 \times 4.95^{2.287}$
$Y = 65.757 \times 38.776$
$Y = 2549.78$ g/tree
$Y = 2.550$ kg/tree
$Y = 2.550 \times 2400$ trees ha^{-1}
$Y = 6120$ kg ha^{-1}
$Y = 6.12$ t ha^{-1} $\times 0.5$
$Y = 3.06$ tC ha^{-1}

Biomass equation coefficients for 20 year old Picea spp. where:
$Y = $ g/tree
$X = 6.6$
$a = 33.722$
$b = 2.712$

$Y = 65.757 \times 6.6^{2.287}$
$Y = 65.757 \times 74.868$
$Y = 4923.10$ g/tree
$Y = 4.923$ kg/tree
$Y = 4.923 \times 2400$ trees ha^{-1}
$Y = 11{,}815$ kg ha^{-1}
$Y = 11.815$ t ha^{-1} $\times 0.5$
$Y = 5.91$ tC ha^{-1}

APPENDIX VI

Potential value of carbon credits from planting speckled alder on rights-of-way

Planting Program	Transmission (ha)	tC ha^{-1}	Distribution (ha)	tC ha^{-1}	Total (tC)
Sustainability	1350	27,109.5	399	6996.32	34, 105.82
FCM Partnership	350	5750.5	25	410.75	6, 161.25
Total	1650	32,860	424	7407.07	40, 267.07

Conversion factor for tons of carbon to tons of carbon dioxide gas (3.667)

$$40{,}267.07 \times 3.667 = 147{,}659.34\ tCO_2$$

Monetary value of carbon dioxide stored assuming a rate of \$15 tCo_2^{-1}

$$147{,}645.92\ tCO_2 \times 15 = \$2{,}214{,}890.19$$

Part XIV
Fire Management

Right-of-Way Management by Eskom, South Africa

Hein F. Vosloo, Winston S.W. Trollope, and Phillip E. Frost

Eskom is the national electricity utility of South Africa and operates approximately 28,000 km of high voltage Transmission lines (132 kV and above) and 250,000 km of Distribution Lines (132 kV and below). The rights-of-way (ROW) or (servitudes) of these power lines form a network over the whole sub continent of southern Africa and traverse a number of biomes, ranging from arid to moist grassland and savanna vegetation. The analysis of eleven years' line fault data indicates that vegetation fires cause in excess of 20% of line faults, with a financial impact estimated at R80m per year. Grass and other biomass fires in Africa have been studied by atmospheric and pasture scientists and has been the subject of extensive research. Similarly the interactions between power lines and birds, where bird droppings cause line faults that have detrimental effects for both birds and the utility. The bird mitigation program has now been ongoing for a number of years and the data collected shows the effectiveness of these measures. Eskom has embarked on the development of life cycle management plans for its transmission equipment and ROWs. The servitude life cycle management plan covers the total spectrum, from concept planning, through EIA and obtaining permits to the maintenance phase and de-commissioning of transmission lines. It also deals with the social, economic and environmental aspects of this management task. As a major part of this plan, the maintenance of vegetation in the ROW, in particular with regard to fires, receives much attention. Most of the research on fire and fire behaviour has been conducted by fire ecologists, using fire as a range management practice for maintaining the forage quality and vigour of the grass sward and controlling the encroachment of undesirable vegetation in grassland and savanna areas. This knowledge on fire behaviour has not yet been applied to the study of the flashovers that occur during fires burning under power lines. During the Austral winter of 2003, Eskom embarked on a project to systematically identify plant communities that pose an increased fire risk to power lines. In addition to the botanical description, phytomass of these plants and their fire behaviour, the spectral signatures for these communities were also obtained. The results from this research will be used to identify problem plant communities and this paper will discuss the methods that were used and report on the results obtained. During 2004 Eskom embarked on a project of detecting grass fires in near real-time using satellites. A description of this system and the initial results will also be discussed in this paper.

Keywords: Electrical grid, line faults, bird streamers, flashover, satellite fire early warning system, fuel load, fire intensity, fire danger indices, servitude life cycle management plan, fuel score, MODIS, MSG, right-of-way

INTRODUCTION AND BACKGROUND

The Eskom grid

Eskom is South Africa's national electricity utility and operates a transmission system that covers about 28,000 km (17,500 miles) operating at voltages between 132 kV to 765 kV (see Fig. 1). Electricity is generated predominantly by means of coal-fired power stations, one nuclear station and three hydro peaking stations. The installed capacity of the system is about 40,000 MW and during the winter of 2004 peaks of 34,200 MW were supplied. This constitutes 95% of the electricity used in South Africa (Anon, 2004).

The electricity supply industry started simultaneously with the discovery of diamonds (1882) and gold (1886) and has always been closely associated with the

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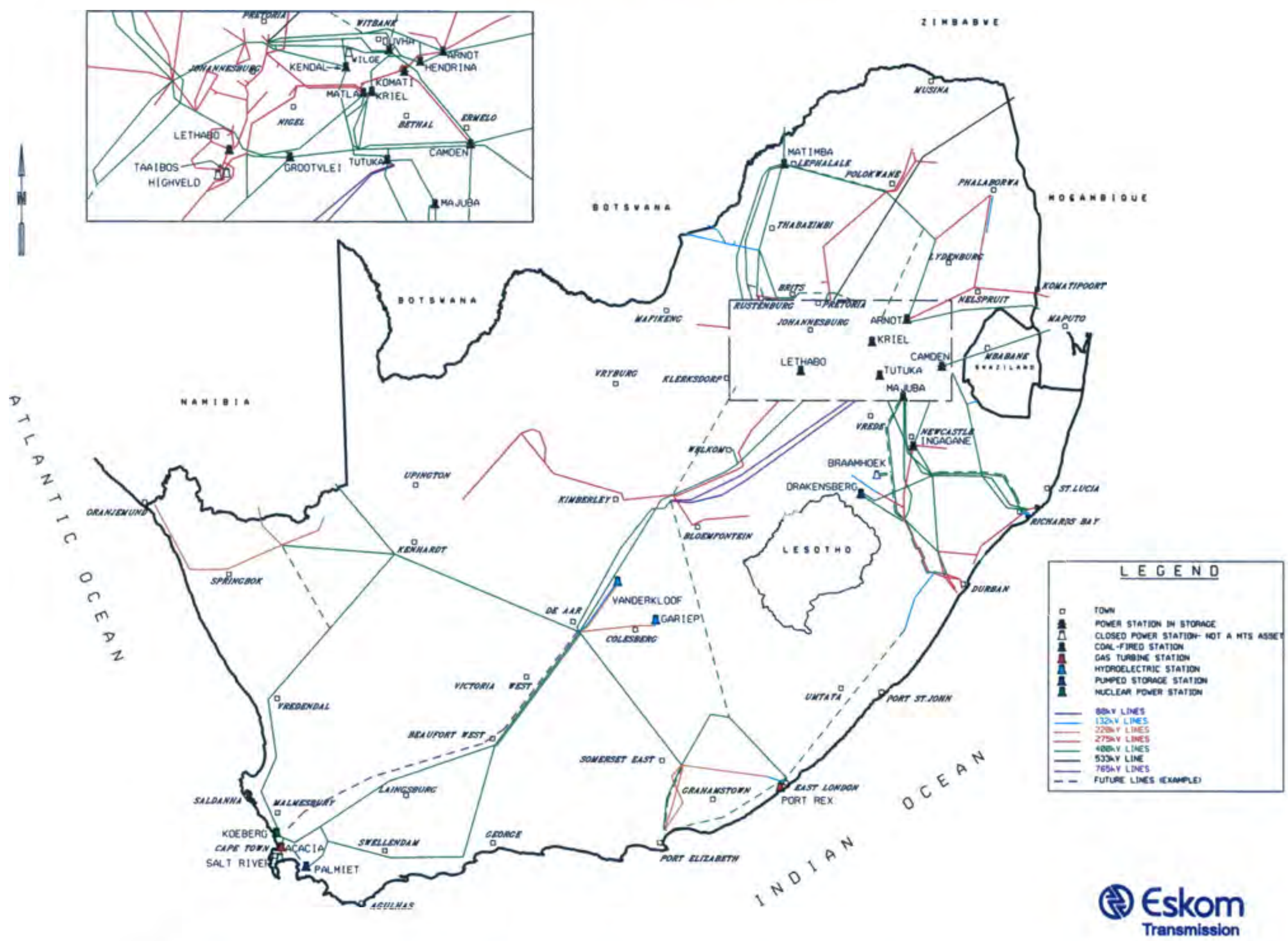

Fig. 1. A schematic representation of the Eskom Transmission grid and generation system in South Africa.

industrial development of the country (Conradie and Messerschmidt, 2000).

As the mining operations on the gold fields of South Africa went deeper underground in search of gold, steam driven plant proved inadequate and was eventually converted to electrical plant. The first coal fired power stations were built as early as 1897 to supply the gold industry. The first transmission line in South Africa was built in 1912 between the Vereeniging power station and the Robinson substation in Johannesburg. It covered a distance of about 50 km (30 miles) and operated at 80 kV (Conradie and Messerschmidt, 2000).

Although extensive use was made of coal, the original idea was to build a hydro electric power station at the Victoria Falls in the current Zimbabwe. This was the idea of Professor George Forbes who designed the first power station at Niagara, but the mining magnates were dubious of relying on a transmission line of over 1000 km (625 miles) and the nearby coal fields were regarded as a safer option (Conradie and Messerschmidt, 2000).

Although the rivers in South Africa are not suited to the generation of hydro electric power, many of the rivers of Central Africa are perennial, have substantial and sustained flows and are ideal for generating electricity. During 1961 there was a proposal to harness the power of the Zambezi River and in 1969 an agreement was finalized between Eskom and Portugal that led to the building of the hydro electric station at Cahora Bassa in Mozambique, which is connected to the South African grid by means of two 1800 km long (1126 miles) DC lines, operating at 550 kV.

Currently, discussions and negotiations concerning the harnessing the hydro energy of the rivers of Central Africa is still ongoing. A project presently is being planned to use the immense hydro energy potential of the Congo River by building a hydro electric station at Inga in the Democratic Republic of Congo (DRC). The long-term plan is to export this energy to the rest of Africa and possibly Europe (see Fig. 2).

Plans are currently underway for the construction of a hydro electric station at Inga in the DRC. This will require a 3600 km (2250 miles) DC line possibly operated at 800 kV. Further plans include the possibility of linking this source to the North African and European electricity grids.

Approximately 80% of the line faults on the Eskom electricity grid originate from natural and biotic causes such as birds, fires and lightning. These faults have important social, economic and environmental consequences and are factors to consider in the management of the ROW.

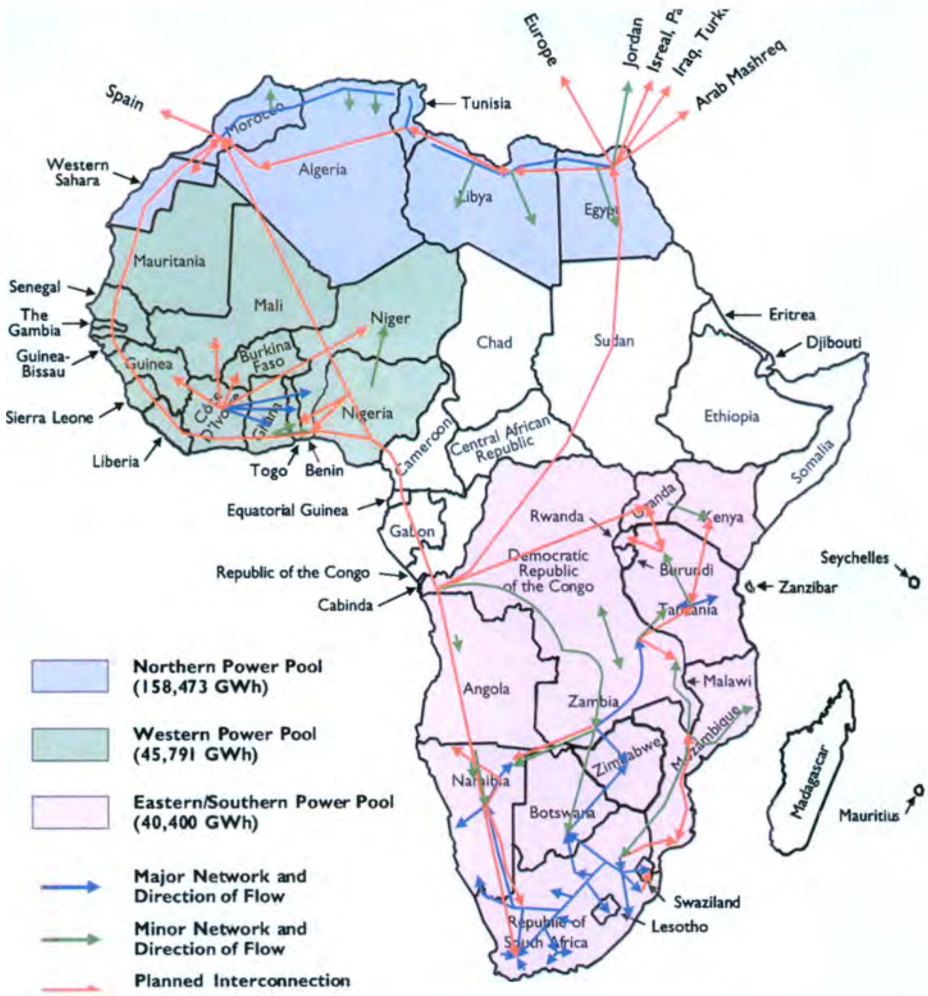

Fig. 2. A schematic representation of the proposed African Grid, showing its possible connection to Europe.

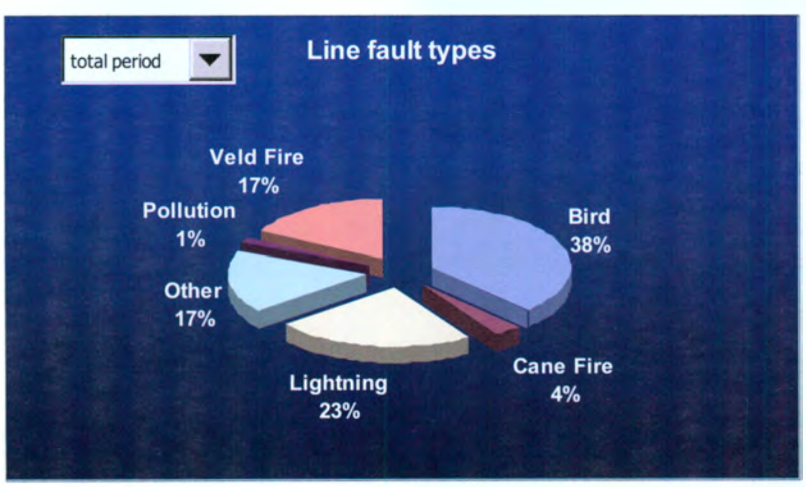

Fig. 3. Line faults for the period 1993–2003 on the transmission system.

CAUSES OF LINE FAULTS ON THE GRID

As a prerequisite for effective servitude management, it is essential that the cause of line faults is determined and preventative practices and solutions are included in the management plans.

During the period 1993 to 2003 some 8202 line faults were recorded. The causes of these faults where known were reported by field staff and the results are presented in Fig. 3. Initially a cause could not be identified for 29% of the faults reported. This was either due to field staff not being able to locate the fault or the cause

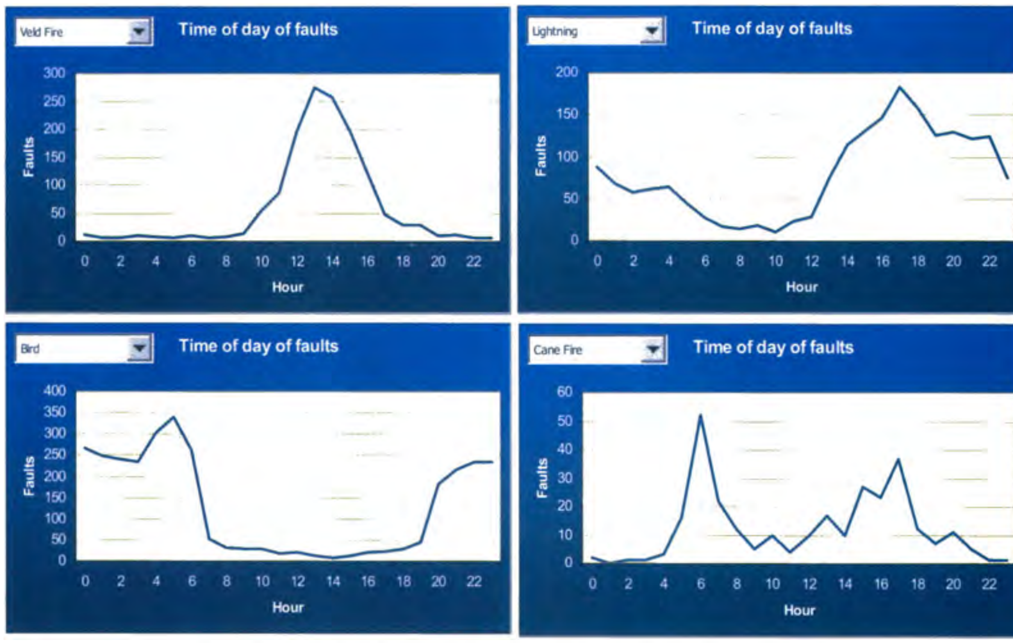

Fig. 4. Time-of-day occurrences for some of the line fault categories.

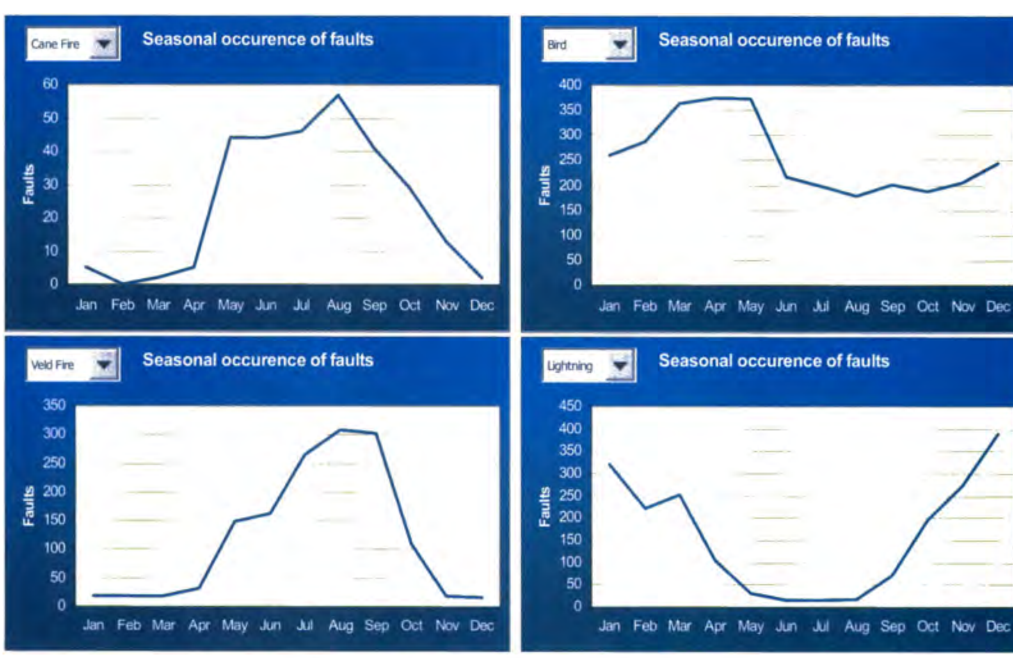

Fig. 5. The seasonal occurrence of line faults.

could not be determined. It later transpired during the 1990's that fecal streamers from birds are an important cause of line faults.

In order to test the validity of the categories of line fault causes presented in Fig. 3, time-of-day and seasonal graphs were drawn for the different types of line faults (see Fig. 4). It is well known that due to climatic and other factors, certain line faults only occur during certain seasons. Lightning, for instance, is a summer phenomenon associated with the rainy season and thunderstorm activity during the latter part of the day. Bird streamers occur predominantly during the night because the responsible bird species hunt for food during daytime and the faults occur while the birds are roosting at night. This bi-modal temporal pattern, first observed by Burnam (1995) has been confirmed. This bird behaviour is further supported by observations made of birds in captivity (Rhodes and Piper, 2004).

The occurrence of line faults caused by cane fires also clearly show peaks at the times when cane farmers normally execute burns, namely at 06:00 and at 17:00 (see Fig. 5). The faults between these peaks are attributed to uncontrolled fires.

The seasonal occurrence of line faults also highlights some interesting facts. Vegetation fires are a winter phenomenon in South Africa and this is clearly borne

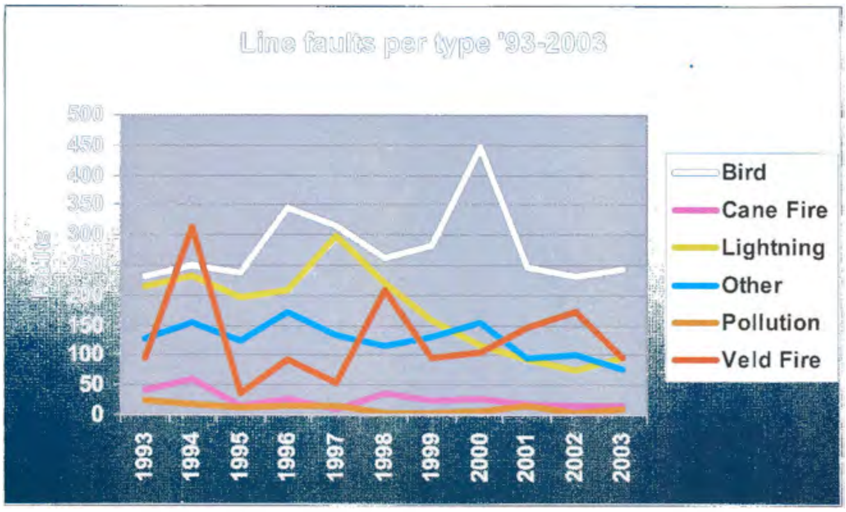

Fig. 6. The variation of line faults during the period 1993–2003.

out by the occurrence of fire related line faults during the Austral winter and in particular during July, August and September illustrated in Fig. 5.

From the analysis of the line fault data it also became apparent that the number of faults vary annually and this is illustrated in Fig. 6. Due to the fact that the majority of line faults can be traced back to weather and climate, the reason for this variation may be explained in dry and wet weather cycles that normally occur in South African weather patterns.

THE EFFECT OF WEATHER AND CLIMATE ON ROW MANAGEMENT

Although the association between weather and the reliability of the transmission system is obvious with lightning-type faults, it was the variation in bird streamer related faults that first highlighted the importance of weather and climate in servitude management.

Although faults caused by bird streamer decreased significantly after the installation of bird guards, their apparent efficacy was influenced by climatic conditions. For example, streamer faults were at very low levels during the period 1993–1995 when South Africa was experiencing a prolonged drought. However, streamer faults increased again during a subsequent high rainfall period that resulted in increased bird populations because of the more favourable environment. Nevertheless the bird guards still reduced the incidence of streamer faults during these wet periods.

The impact of climate on vegetation is a dominant factor (Schultze, 1997) and is well known and documented scientifically. Abundant rains produce high plant fuel loads, especially in the grassland areas of the central interior of South Africa, and is one of the primary factors influencing fire behaviour. Extreme weather conditions such as high air temperatures, low relative humidities and high wind speeds at the time of the fire are equally important (Luke and McArthur, 1978).

The significant effect of atmospheric conditions prevailing at the time of wildfires burning in grasslands impacts negatively on the reliability of electrical transmission systems. This was discovered during a double 765 kV outage experienced on 29 June 2002 (Vosloo, 2002a; 2002b; 2002c). Two of the main transmission lines to the Western Cape Province were tripped out during two separate grass fires and the supply of electrical power was lost. In spite of very low grass fuel loads (see Fig. 7), a flashover occurred. The dominant factors in this case were the weather conditions that existed at the time of the fires. Extreme fire danger indices occurred with wind speeds of 35–45 km/h (22–28 mph) gusting to 65–70 km/h (40–44 mph). Air temperatures ranged between 25 °C and 30 °C (77–86 °F) and the relative humidity was between 10–15%. This incident highlighted the importance of weather conditions during grass fires, and in particular, pre-frontal conditions that include berg winds associated with hot north westerly winds.

As a consequence of the recognition of the effects of weather conditions on fire behaviour, daily fire danger forecasts as described by fire danger indices (FDI's) have been instituted in Eskom's Transmission Division since 2002. These forecasts include air temperature, wind speed and direction, relative humidity and FDI. These data are supplied for a seven-day period and are widely used as part of the Eskom maintenance outage scheduling program.

Luke and McArthur (1978) in Australia defined FDI as "The Fire Danger Index is a relative number denoting the combined evaluation of the inflammability of forest fuels and the rate of spread of fire in such fuels for specific combinations of fuel moisture content and wind velocity." The authors feel that this definition does not quite describe the concept of the FDI and its effect on grassland fires occurring under ESKOM

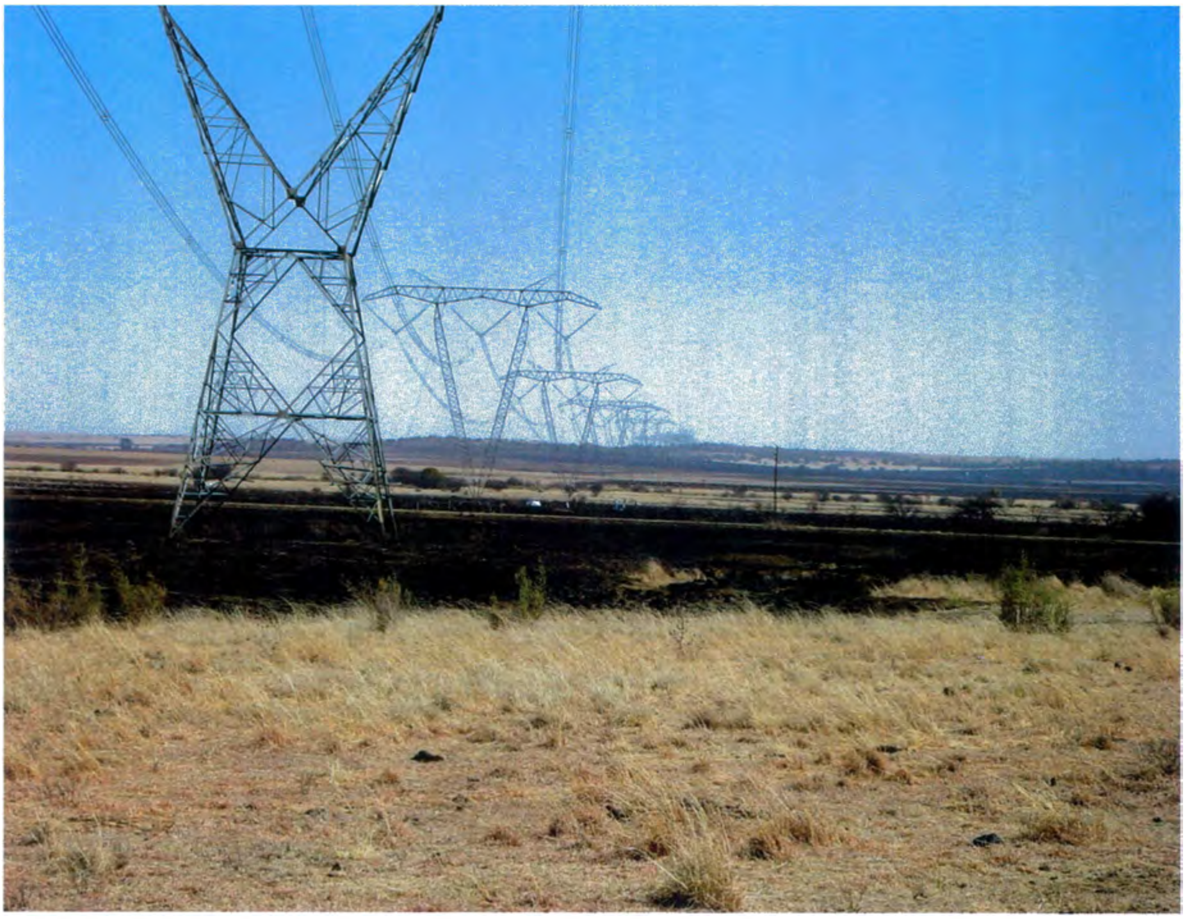

Fig. 7. The site of the flashover on the 765 kV transmission line. Note the low grass fuel loads in the unburnt area.

Transmission lines and ventures to propose the following definition for the purposes of this paper; "The Fire Danger Index is a numerical index describing the flammability and potential fire intensity of plant fuels as influenced by air temperature, relative humidity, wind speed and degree of curing."

THE LIFE-CYCLE MANAGEMENT PLAN FOR SERVITUDES

Introduction

During 2002, Eskom's Transmission Technology Department embarked on a project to develop life cycle management plans (LCMP) for various items of equipment such as transformers and circuit breakers used in the transmission of electricity. Although transmission servitudes could not be strictly classed as "equipment," a LCMP was also required for transmission servitudes (or right-of-way) as well as transmission lines.

The management of the transmission lines, consisting of structures, insulators and conductors requires a strong technology-engineering focus. Conversely the management of servitudes involves biotic, legal and social aspects. This requires different disciplines and skills and it was therefore decided to investigate these two fields as two separate studies.

Need for integrated servitude management

Traditionally the environmental and operational management of transmission lines often involves two divergent activities. In the case of environmental management, it has a strong conservation focus without much concern for operational realities. Conversely, with operational management maintaining the flow of electricity at all costs is dominant.

Similarly, the construction of power lines has the timely completion of the project as its main goal. Poor relationships with landowners that often result during the construction phase inevitably have a negative effect on the maintenance staff and their ability to carry out their task. If the maintenance staff do not develop a good rapport with landowners, it becomes extremely difficult to obtain new servitudes. As a result, the management plan has to consider the entire life cycle of the servitude and to integrate both operational and environmental aspects by minimizing environmental impacts, whilst optimizing operational aspects.

Purpose and scope of the servitude management plan

The life cycle management plan for servitudes involves the management of the animal, vegetation and social aspects of the servitude. It also deals with the activities associated with the entire life cycle of the servitude, viz. planning, environmental impact assessments

(EIA's) and issuing of permits (permitting), construction, maintenance and decommissioning processes associated with transmission lines (Vosloo, 2003c).

The plan also identifies gaps between existing practices and the ideal and contains action plans for the rectification of these deficiencies. This plan also links into the capital and operational budgets.

Animal interactions
As has been shown above, the majority of power line and animal interactions, concern birds. Aspects that are dealt with include collisions, nesting and bird streamer management. In each case, guidelines have been developed for the management of these aspects (Vosloo and van Rooyen, 2002; 2003a; 2003b).

Generally, the electrocution of birds on the Eskom transmission lines is a phenomenon that does not normally occur because with transmission voltages greater than 132 kV the air gaps between power lines far exceeds the wingspans of the birds species roosting on the lines. Electrocution is therefore only a problem associated with lower voltage power lines.

Social aspects
Included under social aspects in the LCMP is an array of legislation that pertains to the management of servitudes. This includes both national and provincial legislation that regulates the management of environmental issues such as protected and alien vegetation, the use of herbicides, protection of fauna and prevention of soil erosion. Legislation that deals with EIA's and the permitting of new power lines is also addressed.

The legislation that affects the management of the servitude also includes administrative activities such as registration of servitudes, fencing and the installation of access gates along the fences.

Legislation affecting business activities also has an impact on the management of servitude, thus the Eskom Act, which governs the existence of the utility as well as its obligation to supply electricity, is also dealt with.

Vegetation management
Problems associated with the management of vegetation in servitudes in South Africa differ considerably from that of countries with large natural forests, where care has to be taken with trees that may fall onto power lines. This is generally not a problem in South Africa as few transmission lines traverse the commercial forestry areas.

The majority of problems experienced are in areas where Eskom transmission lines traverse grassland, savanna and fynbos (a highly prized floral kingdom in South Africa). Except for a few instances concerning alien vegetation such as Black Wattle (Acacia mearnsii) flashover problems rarely involve plants growing close to conductors, but rather result from the effect of wildfires associated with certain plant species.

South African vegetation is to a large extent not only adapted to fire, but many species depend on fire for defoliation, reproduction, and seed germination (Bond, 1997). Annually, at the end of summer, the servitude staff has to assess the vegetation in the servitude for fire risks. This is both a tedious and difficult task as the fire risk is not only influenced by the fuel, but also by the prevailing weather conditions. To assist the servitude staff, quantitative methods for the determination of fire risk are being developed.

In addition to the management of the vegetation for fire risk, the servitude manager must also balance this with the risk of causing accelerated soil erosion or affecting the grazing practices of the relevant land owner as well as taking cognizance of legislation pertaining to alien and protected plant species. It must be noted that Eskom does not own the land in question, but only has a right to convey electricity across it.

Whilst the LCMP is considered a major step in consolidating all the aspects that are important for the management of servitudes, it should be recognised that it is a dynamic process that will require numerous updates as knowledge increases.

FIRE RESEARCH

Introduction and problem statement
Eskom power lines traverse the whole sub-continent of southern Africa and the right-of-way passes through a wide diversity of plant communities that include grassland, savanna, forest, fynbos and karroo vegetation.

During uncontrolled wildfires several plant species have been observed as generating flame heights sufficient to bridge the gap (8 m) between the earth and the power lines resulting in a line fault. It was therefore decided to conduct a fire behaviour trial to determine the potential of specific plant species to generate different fire intensities and flame heights under different atmospheric conditions, notably air temperature and relative humidity. This study focused on plant communities containing significant stands of Cosmos bipinnatus (Cosmos), Tagetes minuta (Khakibos), Protoasparagus laricinus (Katbos) and Acacia mearnsii (Black Wattle) and formed part of a wider investigation on the use of hyper spectral scanning technology to identify plant communities with a high risk of causing fires that will cause flashovers in transmission lines.

Burn sites
The project was conducted in the Bankenveld veld type (Acocks, 1975) in the Guateng Province of South Africa where the aforementioned plant species form abundant components of the vegetation in certain areas. Initially eight plots ranging in size from 0.5–2 ha were selected on the basis of having significant stands of Cosmos, Khakibos, Katbos and Black Wattle present.

However, at the time of the application of the controlled burns two of the selected plots were abandoned because they had insufficient grass fuel present to generate a high intensity fire.

Range condition

Range condition refers to the condition of the vegetation in relation to some functional characteristic/s (Trollope et al., 1990). In the context of the vegetation growing underneath the ESKOM power lines, the condition of the rangeland relates to its potential to produce plant fuel that will generate fire intensities and flame heights that may cause a line fault resulting in a power failure.

Research in the Kruger National Park has shown that it is both feasible and practical to describe quantitatively the condition of the grass sward in terms of its potential to produce grass fuel that significantly influences the intensity of a fire (Trollope, 1990). This is referred to as the fuel score of the grass sward and involves allocating fuel factors to the different herbaceous species occurring in the grass sward on a scale of 1–10. A fuel factor of 10 indicates a high genetic potential for a plant species to produce high fuel loads of flammable plant fuel and vice versa. This procedure was used to describe the condition of the vegetation in the sample sites that were burnt in the fire behaviour trial. This information could also then be used to assess the potential of the vegetation to generate fire intensities and flame heights growing in similar circumstances under power lines. However, during the trial there were too few Katbos shrubs present in the sample sites to provide an adequate assessment of its potential to generate high intensity fires with significant flame heights. Also in one of the sample site where trees and shrubs of Black Wattle were present, the grass fuel load was either too low, or in places absent, to enable the fire to ignite this species to any significant degree. Consequently the assessment and description of the condition of the vegetation in the sample sites that were burnt during the trial were limited to the grass sward and reflects its potential to produce plant fuel comprising grass and non-grass species (Cosmos and Khakibos) and its ability to generate different fire intensities and flame heights.

Botanical surveys of the grass sward in the sample sites were conducted prior to the application of the controlled burns and comprised a point quadrant survey where the nearest rooted herbaceous plant was recorded at approximately one meter intervals along two transects sited down the center of each half of the sample site. A total of 100 points were recorded per sample site. An index of the basal cover of the grass sward was also obtained by recording the point to tuft distance of the nearest rooted plant to each of the 100 point quadrants. In situations where the point to tuft distance was greater than 25 cm this was recorded as bare ground.

Fire behaviour

Fire behaviour refers to the release of heat energy during combustion as described by fire intensity, rate of spread of the fire front, flame characteristics and other related phenomena (Trollope et al., 1990). The primary factors affecting fire behaviour are fuel load, fuel moisture, air temperature, relative humidity and wind speed (Luke and McArthur, 1978).

Fuel load

The fuel load of the grass sward, expressed in kilograms per hectare, was estimated shortly prior to burning the different sample sites using a Disc Pasture Meter as described by Bransby and Tainton (1978). This comprised recording the settling height of the disc at 100 randomly allocated recording points arranged in two rows down the center of each half of the different sampling sites. The mean disc height was used to estimate the grass fuel load using the calibration developed by Trollope and Potgieter (1986) in the Kruger National Park and which has been found to be applicable to a wide range of grassland and savanna ecosystems in southern and east Africa (Trollope et al., 2000).

The calibration equation is:

$$Y = 3019 + 2260\sqrt{X}$$

where:

Y = mean fuel load, kg/ha

X = mean disc height, cm

The disc pasture meter used for estimating grass fuel loads is illustrated in Fig. 8.

Air temperature, relative humidity and wind speed

The air temperature (°C), relative humidity (%) and wind speed (km/h) were recorded during the duration of the controlled burns with an automatic weather station. The mean values for these parameters were used to characterise the weather conditions prevailing during the application of the different controlled burns.

Rate of Spread (ROS)

The forward rate of spread of the fire front, expressed in meters per second, was estimated by visually recording the time the fire moved from one point to another in the different sample sites. Care was taken to ensure that the distance traveled by the fire front during the recording was as great as possible to ensure that the estimate of the rate of spread was representative of the behaviour of the fire in the particular sample site as a whole. The rate of spread measurements were limited to head fires burning with the wind as these represented the type of fire that was intended to burn out the majority of the area of the sample sites. The focus of interest in this trial was on the behaviour of head fires because this type of fire has the greatest potential to develop extreme fire intensities and flame heights capable of causing flashovers in the ESKOM transmission lines in contrast to backfires burning against the wind.

Fig. 8. The disc meter that was used to determine fuel loads during the fire experiments.

Fire intensity
The most commonly used description of fire intensity is that defined by Byram (1959) who defined it as the amount of heat energy released per unit time per unit length of fire front expressed in kilojoules per second per meter. This is also referred to as the fire line intensity and can be represented as:

$$I = Hwr$$

where:

I = fire intensity – kilojoules per second per metre, kJ/s/m

H = heat yield – kilojoules per kilogram, kJ/kg

w = mass of available fuel – kilograms per square metre, kg/m^2

r = rate of spread of the fire front – metres per second, m/s

Research on fire behaviour and fire effects in the savanna areas of South Africa has led to the conclusion that fire intensity is the parameter that best describes the overall behaviour of a fire and it is recognized as being one of the important components of the fire regime (Trollope, 1999).

Fire intensity was estimated in two ways during the application of the controlled burns to the different sample sites. Firstly, the overall fire intensity was measured using the formula described by Byram (1959) together with the estimates of the fuel load and rate of spread recorded for each of the sample sites. The heat yield of 16,890 kJ/kg used in the formula was that measured by Trollope (1999) and represents the amount of heat energy available for release per unit mass of fuel. This value may have been slightly too low for the plots that had significant amounts of Cosmos and Khakibos present in the fuel load. However, in the absence of empirically based estimates of the heat yield for these two species this value was considered adequate for the purposes of this initial study.

The second method used for estimating fire intensity was the hydropyrometer technique developed by Webber and Trollope (1999), which has the ability to measure the fire intensity that occurs at a particular point in a vertical profile.

The fire intensity is estimated by recording the heat of vaporization of water boiled off during a fire at a specific point. This is estimated by placing 20 ml of distilled water in a 340 ml aluminum beverage can and recording the loss of water from the can during a fire. Replicates of six cans were placed at ground level, the mean canopy height of the herbaceous layer of vegetation, one and two meters above the mean canopy height of the herbaceous vegetation. This procedure ensured that the intensity of the fire was measured in a vertical profile, at specific points relative to the morphology of the herbaceous plant communities present in the different sample sites.

The amount of water placed in the cans and the amount vaporized during the fire were measured volumetrically as accurately as possible. The placement and arrangement of the cans at different heights above the ground are illustrated in Fig. 9.

The fire intensity estimated at and above ground level at the different sample sites was calculated using the following formula developed by Webber and Trollope (1999) for a 340 ml aluminum can with a diameter of 6.66 cm and a height of 12 cm.

$$\text{Fire Intensity} = \left[\frac{\text{Water Loss (ml)}}{\pi r^2\,(\text{m}^2)} \times 2.571 \times \frac{\text{ROS (m/s)}}{1}\right]$$

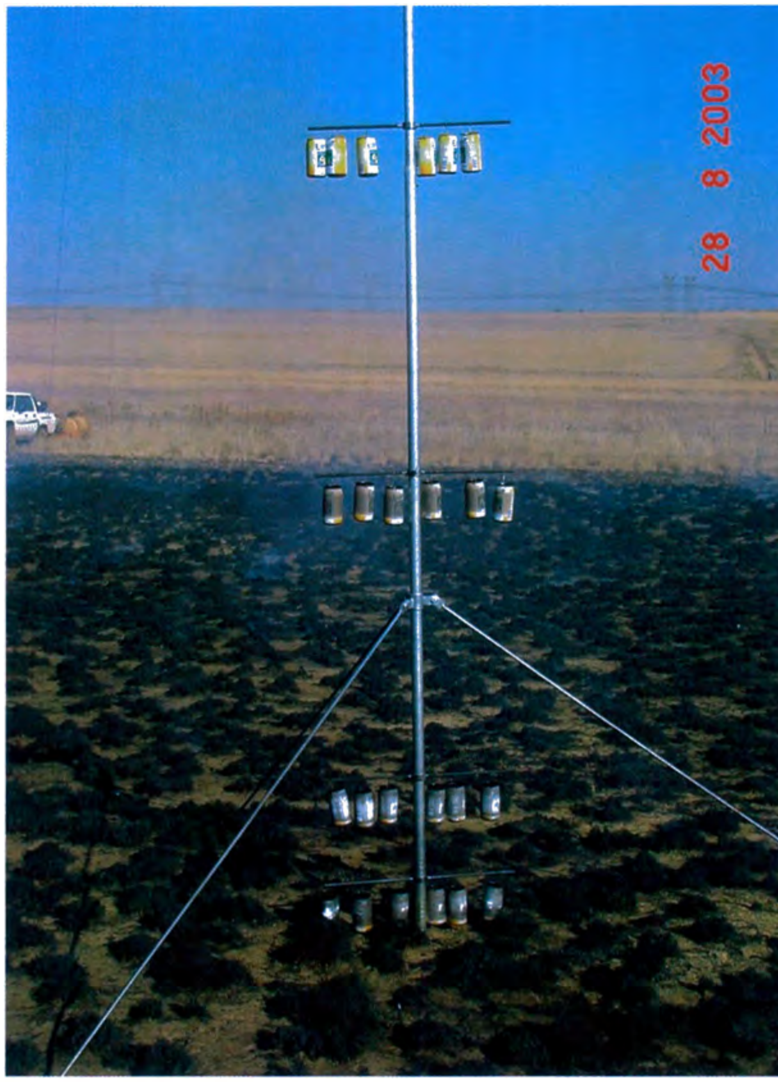

Fig. 9. An example of the hydropyrometer. The cans were placed at heights as described in the text.

This can be simplified to the following formula for estimating fire intensity at a particular point:

$$\text{Fire Intensity} = \text{Water Loss (ml)} \times \text{ROS (m/s)} \times 734.5714 = \text{kJ/s/m}$$

Flame height

This is defined as the perpendicular height of flames from ground level expressed in meters (Trollope et al., 1990). In terms of this study, flame height is a critical fire behaviour parameter to measure as it provides a means of being able to relate the behaviour of fires to the flashover problem in ESKOM power lines. It is a highly variable parameter that is difficult to measure precisely in practice and because it is highly correlated with fire intensity (Trollope and Potgieter, 1985), which is easy to measure, it has consequently not received significant research attention in South Africa. Nevertheless, considerable effort was made to estimate and record the height of the flames during the application of the controlled burns to the different sample sites. Firstly, this was done subjectively during the fires by relating the height of the flames to objects of known height located in the sample sites. Secondly, all the fires were photographed with a digital video camera from which estimates of the maximum and mean flame heights were obtained. Also where possible photographs were taken with a digital still camera and used to estimate the height of the flames.

Results and conclusions from the fire behaviour trial

It can be concluded that the objectives of the fire behaviour trial were achieved. Firstly it was clearly demonstrated that fuel load plays a dominant role in determining the intensity of a fire. For example in Site 6, which had a low grass fuel load (751 kg/ha), the fire intensity was correspondingly low (190 kJ/s/m) whereas in Site 5 where the grass fuel load was significantly higher (2,853 kg/ha) the fire intensity was much greater (3,903 kJ/s/m).

The significant effect of atmospheric conditions represented by air temperature, relative humidity and wind speed (FDI) on fire intensity was also demonstrated by the difference in fire intensity between the

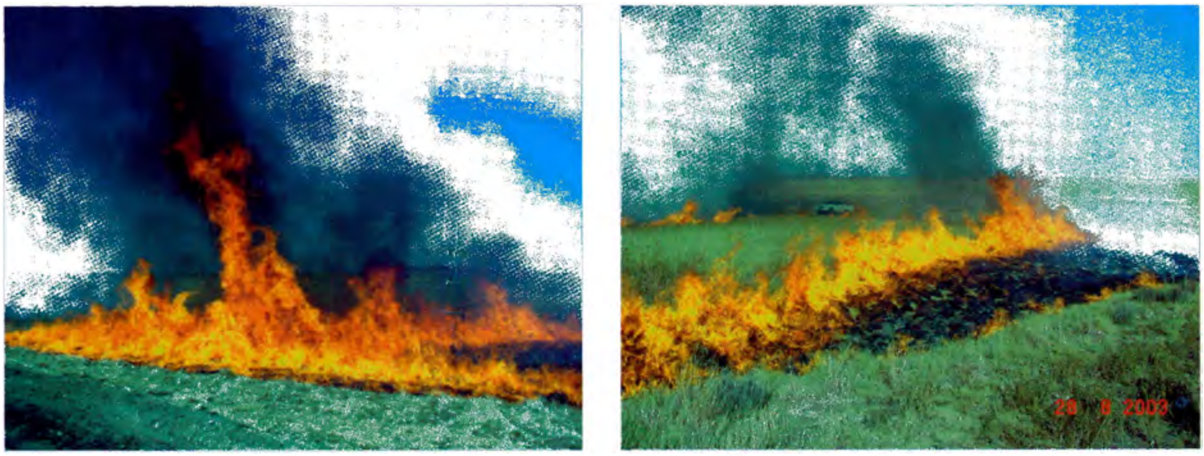

Fig. 10. Contrasting flame heights of fires generated by Cosmos/Khakibos (left) and Eragrostis curvula dominated plant communities (right) respectively.

fires in Site 1b and Site 8 where the grass fuel loads were similar. In Site 1b, the fire was applied when the air temperature was 25.6 °C, the relative humidity 18.2% and the FDI 62 resulting in a fire intensity of 2,798 kJ/s/m. Conversely in Site 8 the air temperature was 20.8 °C, the relative humidity 27.3% and the FDI 48 resulting in a fire intensity of 2,370 kJ/s/m.

Another important outcome of this trial was the objective assessment of the fire intensity potential of the different herbaceous plant fuels. The identification of Cosmos and Khakibos as types of fuel that have a significantly higher potential than any of the dominant grass species in the Bankenveld of Gauteng Province i.e. Eragrostis curvula, Hyparrhenia fillipendula and H. hirta is of particular significance (see Fig. 10). It provides quantitative confirmation of previous field observations that these two plant species are prime culprits in exacerbating fire intensities and flame heights of wildfires burning under extreme atmospheric conditions resulting in line faults in the Eskom transmission lines.

The preliminary determination and demonstration that the high flammability associated with Cosmos and Khakibos can be incorporated into a botanical survey technique that can be used to assess the potential of the grass sward to generate extreme fire intensities and flame heights, is of significant practical value. This requires further testing in the field, but based on the use of this approach in assessing the condition of rangeland for other functional characteristics like forage production and resistance to accelerated soil erosion, there are good grounds to be optimistic about its potential usefulness in the field.

The excellent results obtained with the hydropyrometers in estimating fire intensities has provided valuable confirmation of the scientific and practical value of this technique for studying fire behaviour under practical field conditions in South Africa. Normally, such measurements require expensive electronic equipment that severely limits its use in the field. The availability of a simple, robust and adequately precise method for estimating fire intensity at a particular point in a vertical profile or for a homogeneous area like an experimental plot provides exciting possibilities for exploring fire effects on grass and woody vegetation in the future.

From the results obtained, it has become clear that it would be possible to develop a fire flashover index, aimed specifically for the electrical utility. The FDI currently used was developed to warn of the danger of the onset and spread of wild fires. It was; however, not developed to warn of the flashover risk during a fire. The proposed flashover index will have to be based on the work done on fuels, as described above, as well as include the weather and atmospheric conditions and the electrical gradient of the line in question. In order to execute this in near real-time, extensive use will have to be made of satellite technology, including hyperspectral methods.

SATELLITE FIRE EARLY WARNING SYSTEM

Fire early warning systems around the World

The early identification of a fire is generally accepted as crucial to its successful suppression. To this end, fire fighters have used lookout posts during high-risk fire weather to spot fires. Airborne spotters are also used during fire fighting exercises.

An early example of a satellite based forest fire detection system was initiated by VTT Automation in Finland during the period 1994 to 1998. This system used data from the NOAA satellites during four pilot experiments to detect fires as small as 0.1 ha. Local fire authorities were alerted by fax within approximately 31 minutes on average from the time of receiving the data. The system correctly detected 83% of the fires (Kelhä, 1998).

The only means of accurately determining the exact location and extent of a fire is to have a global perspective from space, making space-based measurements extremely important. Until recently, no satellites have been dedicated to fire monitoring and measuring. Most observations of fires from space have been obtained from existing satellites developed for other purposes. Fire measurements predominantly came from the Advanced Very High Resolution Radiometer (AVHRR) on the National Oceanic and Atmospheric Administration (NOAA) series of satellites.

Earth observation (EO) satellites have been scanning and orbiting the earth since the mid 1970's. The Meteosat series of geostationary satellites were the first to be launched. Geostationary satellites are placed in fixed orbits moving at the same speed as the earth's rotation. This enables them to record imagery over the same area constantly. Geostationary satellites are in the region of 36,000 km from earth and have a low image resolution. The frequency of images taken is; however, high (every 30 min).

Polar orbiting (EO) satellites have also been operational since the late 1970's. The NOAA satellite series has been operational since 1978 with NOAA 1. NOAA 17 was launched in 2002 and will continue until the year 2014. Polar orbiting satellites like NOAA, orbit the earth every 103 minutes crossing the north and south poles 14 times per day as the earth rotates from west to east. NOAA can provide a daily image of an area at 1 km resolution.

Earth Observation Systems (EOS) of NASA launched their new generation earth observations satellites TERRA and AQUA. Both of these satellites carry the Moderate Resolution Image Spectroradiometer (MODIS) sensor. These sensors scan the earth eight times a day in 36 spectral bands including a mid infra red band dedicated to fire detection.

Day and night-time images provide information on the location and frequency of active fires. The satellite system assists in the detection and monitoring of fires, and aids in determining the size of areas burned. Remote sensing of global fires indicates that Africa is the "fire center" of the planet with more biomass consumed by fire in Africa than anywhere else on Earth.

Active fires can be detected by satellites that scan the earth in the 3.6–3.9 μm wavelengths. These wavelengths fall within the mid infrared section of the Electro Magnetic spectrum. The current NOAA archive at CSIR Satellite Application Centre (SAC) will enable the generation of a 17-year active fire record. The production of such an active fire archive will provide valuable information on fire frequency, distribution and intensity. The MODIS sensor was developed to detect fires at numerous narrow wavelengths. This enables the MODIS sensor to detect smaller fires (200 × 200 m) where older satellites such as NOAA can only detect fires with a size of (400 × 400 m). The type of land cover and intensity of the fire also plays a role in detection of a hot spot.

The Meteosat Second Generation (MSG) geostationary satellite that was launched in 2002 will enable the detection of fires at a 5 km resolution every 15 minutes. The entire African continent is scanned with each image providing a holistic view on all environmental activities during day and night. Additional weather information such as humidity and surface temperature from MSG will also improve current fire management practices.

Recognising the benefits of EO information, the National Department of Agriculture made a multi-million rand grant- to the CSIR SAC to procure a MODIS receiving and processing system.

Kongsberg Spacetec in Norway has been awarded the contract to upgrade the SAC's Earth Observation Data Centre (EODC) for MODIS and NOAA reception.

As custodian of the MODIS system, SAC will install, maintain and operate the MODIS acquisition and processing system. The system will deliver comprehensive MODIS products and services for the entire South African Development Community (SADC) region in 2004, when it will be fully operational. MODIS will add substantial value to South Africa's efforts to ensure disaster monitoring and food security in southern Africa.

ESKOM, CSIR DME PROJECT

During January 2004, the Satellite Application Centre (SAC) of South Africa's Council for Scientific and Industrial Research (CSIR) approached Eskom with a proposal for a satellite based fire detection system. The challenge of supplying 15-minute data was accepted by SAC and by early April 2004 a prototype of the system was launched as an Eskom research project.

It was clear from the outset that the system had a wider application than only that of Eskom. Other obvious users included the national and local disaster management departments and the forestry industry.

After being approached, the National Disaster Management Department readily joined the project. At the time of writing, numerous fire fighting and disaster management centers are gaining access to the system in anticipation of the high fire season during August 2005.

Operational requirements for an early warning system

The operational requirements of Eskom for a satellite based fire early warning system are rather stringent. A view of the position of fires in close proximity to power lines is required in near real-time at 15 min intervals. This would permit the staff at Eskom's National Control center to monitor the transmission grid and fires in real-time and where necessary to switch any lines out that are threatened by fires. Equally important, is that it would permit the switching back on of lines once the fires have passed.

Fig. 11. A view of the fire detection system as may be viewed on the Internet.

The detection of any existing fire could at best only be done after a well-positioned overhead pass of a polar orbiting satellite. This prompted research into the use of a geo-stationary satellite. These data could be downloaded at shorter intervals but had the less favorable characteristic of being of a lower resolution. The MSG geostationary satellite that was launched in 2002 is providing Africa with a unique opportunity of detecting fires every 15 minutes. The coarse resolution of the pixels is a major constraint with MSG. Each pixel represents an area of 4.8 × 4.8-km in size. Small fires are not easily detected with the system due to this coarse resolution, but thanks to its 15 minute viewing capability fires can be detected as soon as they are approximatly 5 ha in extent.

The final fire detection system will also include a fully automated alarm system. This alarm system will operate via a mobile telephone text message system and will alert the responsible person should a fire be detected within a specified distance from a power line or within a defined area such as a nature reserve.

Eskom's National Control Center will also be connected with the system. A fire that is detected will also trigger the control room's existing alarm system (ENCOR). It is envisaged to extend this facility to other users such as disaster management control rooms.

Interaction with fire fighting associations

As was indicated above, Eskom has an extensive program for reducing fire risk through its vegetation management program. In addition to this program, Eskom has contracted a number of the commercial firefighting associations to assist in the suppression of wildfires. Due to the lack of fire fighting resources, Eskom has to rely on the larger fire fighting community to contain their fires.

South Africa has recently promulgated a new National Veld and Forest Fire Act (Act 101 of 1998). The act makes provision for the formation of Fire Protection associations, which consist of local authorities and communities. It is anticipated that these associations could also make good use of the system.

Results and future plans

Initial results are promising and in a number of cases, fires were detected in remote areas and fire fighters were alerted. The combination of using MODIS and MSG observations appears to be working satisfactorily.

At the time of writing, data are being recorded of the size and type of fires that can be detected with the satellite early warning system. The algorithm for detecting fires using MSG data is also being refined as experience in its use develops. A full report on the system will be drafted towards the latter part of 2004.

The total scanning time of the MODIS scanner over South Africa is approximately five minutes and only occurs 4 times in a 24 hour period, fires that start after the pass and are extinguished prior to the next pass, will of course not be detected by the system. On the other hand the MSG system provides data every 15 minutes but lacks the finer resolution of MODIS. It can therefore to be expected that some smaller fires will not be visible but experience to date shows that a proficient operator is able to gain a wealth of information from the system as well as track the progress of fires reliably (see Fig. 11).

CONCLUSION

Judging by recent power outages in USA, Canada, and Italy, the management of the ROW is of very significant concern to the electricity utility and its customer. The ROW is a vast, complex, and costly resource that has to be managed in an integrated manner. A holistic life cycle approach to this task is proposed as the appropriate procedure to be used. However, from the examples presented in this paper it is clear that because of its complexity, only a multidisciplinary team can effectively execute this task. The use of the latest technology, such as satellite tracking systems, makes this an ideal and exciting arena for future research.

REFERENCES

Acocks, J.P.H. 1975. Veld types of South Africa. Mem. Bot. Surv. S. Afr. No 40. Govt. Printer, Pretoria.

Anon. 2004. Eskom Annual Report 2003. http://www.eskom.co.za.

Bransby, D.I. and N.M. Tainton. 1977. The disc pasture meter: possible applications in grazing management. Proc. Grassl. Soc. Sth. Afr. 12: 115–118.

Burnham, J.T. 1995. Bird streamer flashover on FPL transmission lines. IEEE Trans. Power Delivery, vol. 10, pp. 970–077, Apr. 1995.

Conradie, S.F. and L.J.M. Messerschmidt. 2000, A Symphony of Power. Johannesburg. Van Rensburg.

Kelhä, V. 1998. Satellite based forest fire detection and automatic alert system-Pilot experiment. http://www.gfz-potsdam.de/ewc98/abstract/kelha.html.

Rhodes, G.E. and S.E. Piper. 2004. Report: Vulture Streamer Analysis. Setting up an experiment to measure mass and frequency of Cape Griffon Vulture streamers and their chemical composition. Unpublished Eskom report.

Luke, R.H. and A.G. McArthur. 1978. Bush fires in Australia. Australian Govt. Pub. Serv., Canberra.

Tainton, N.M. 1999. Veld burning. In: Veld management in South Africa. University Natal Press, Pietermaritzburg, South Africa: 217–245.

Trollope, W.S.W. 1990. Development of a technique for assessing veld condition in the Kruger National Park. J. Grassld. Soc. South. Afr. 7(1): 46–51.

Trollope, W.S.W. 1999. Fire Behaviour. In: Veld Management In South Africa. Ed. N.M. Tainton. University Natal Press, Pietermaritzburg: 218–228.

Trollope, W.S.W. and A.L.F. Potgieter. 1985. Fire behaviour in the Kruger National Park. J. Grassld. Soc. Sth Afr. 2(2): 17–22.

Trollope, W.S.W., L.A. Trollope, and O.J. Bosch. 1990. Veld and pasture management terminology in southern Africa. J. Grassld. Soc. South Afr. 7(1): 52–61.

Trollope, W.S.W., J.H. Hines, and L.A. Trollope. 2000. Simplified Techniques for Assessing Range Condition in the East Caprivi Region of Namibia. Final Report of the Namibia–Finland Forestry Programme in the east Caprivi Region of Namibia. Department Livestock and Pasture Science, Faculty of Agriculture, University Fort Hare, Alice: 1–67.

Trollope, W.S.W. and L.A. Trollope. 2004. Final Report on the Fire behaviour Trial conducted to estimate Flame heights and fire intensities generated by different plant fuels in the Bankenveld veld type in Gauteng Province for Eskom, South Africa. Eskom unpublished report.

Vosloo, H.F. and C.S. van Rooyen. 2002. Transmission Bird Collision Guideline. Eskom Transmission Guideline TRMAGAAZ8.

Vosloo, H.F. 2003. Transmission Vegetation Management Guideline. Eskom Transmission Guideline TRMAGAAZ7.

Vosloo, H.F. and C.S. van Rooyen. 2003a. Transmission Bird Perch Guideline. Eskom Transmission Guideline TRMAGAAZ2.

Vosloo, H.F. and C.S. van Rooyen. 2003b. Transmission Bird Nesting Guideline. Eskom Transmission Guideline TRMAGAAZ3.

Vosloo, H.F. 2003. Servitude Life Cycle Management Plan. Eskom Transmission Guideline TRMBPAAB8.

Vosloo H.F., F. Witbooi, and D. Payne. 2004. 2003 Line Performance Analysis and Line Fault Improvement Plan. Unpublished Eskom Transmission report.

Webber, L.N. and W.S.W. Trollope. 1999. A simplified method for measuring fire intensity in grassland fires in the False Thornveld of the Eastern Cape. Department Livestock and Pasture Science, University Fort Hare, Alice, South Africa: 1–16.

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Development of a Wildfire Risk Management System for British Columbia Transmission Corporation's Rights-of-Way

B.A. Blackwell, G. Shrimpton, F. Steele, D.W. Ohlson, and A. Needoba

In 2003, B.A. Blackwell and Associates Ltd. began a project to develop a Wildfire Risk Management System (WRMS) for British Columbia Transmission Corporation's (BCTC) (11,00 kilometers) Rights-of-Way (ROW) across the province of British Columbia. Fuel hazard issues in the ROW are due largely to historic reliance on hand slashing in some areas. These fuels are cause for concern, particularly in terms of BC Transmission Corporation's degree of responsibility for damage caused by fire spreading from the ROW into adjacent areas. Until now, BCTC has lacked a systematic method for prioritization of fuel hazard mitigation treatments. It is intended that the development of the Wildfire Risk Management System will address the following:

1. Provide a foundation for the development of a risk management zonation strategy;
2. Provide a framework on which to assess and prioritize fuel hazards;
3. Promote the development of new guidelines for vegetation management on the ROW;
4. Promote reduction of fire risk to critical infrastructure;
5. Support public communication and education of fire risk; and
6. Support interagency planning and cooperation in the development of fire management strategies.

In simple terms, we want to know at any given location and at any given time, what is the probability of wildfire occurring, and what are the potential consequences (for a given wildfire behavior) on valued resources. This enables fire and resource managers to design strategies and tactics for fire management that vary from high probability-low consequence to low probability-high consequence fire risks across the ROW. The generic approach underlying the WRMS allows its application in a wide range of fire management planning circumstances from timber supply areas to protected areas and interface communities.

Keywords: Wildfire, risk management, integrated vegetation management, IVM, rights-of-way, vegetation management, wildfire risk management system, WRMS

INTRODUCTION

The past two decades have seen tremendous advances in the use of Geographic Information Systems (GIS) and spatial modeling techniques to support fire management planning (Salazar and Nilsson, 1989; Blackwell et al., 2003). More recently, a variety of GIS applications have been developed to support the specific requirements of wildfire risk assessment and management (Bachmann and Allgower, 1998; Gollberg et al., 2001). The goal of these applications is to quantify wildfire risk in a spatially explicit manner, thereby providing managers with a risk management decision-support system.

The 2003 fire season in the Province of British Columbia, Canada was the most severe on record, with 266,000 hectares of land affected by fire (Filmon, 2004). The direct cost to the Province as a result of these fires was estimated at $375 million (Forest Protection Program, 2004) and this value excludes the direct costs to private landholders and indirect costs to the Province and private businesses through

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loss of tourism and other economic revenue. British Columbia Transmission Corporation (BCTC) lost 32 km of wood pole lines in the 2003 fires. Financial losses were incurred by BCTC while customers were without power, and repairs to restore power transmission in fire-affected areas totaled $4 million. The magnitude of these losses highlighted the need for BCTC to identify and quantify the risk of wildfire occurring on their rights-of-way (ROW) so that treatments could be undertaken to minimize the risk of future catastrophic wildfires. An additional consideration is whether surface fuels on the ROW could fuel fires that then spread into neighboring forest and wildland urban interface areas resulting in loss of non-BCTC assets. Public anxiety with regard to fire has increased since the 2003 fire season and it is possible that BCTC may risk litigation for future damages caused to public and/or private property if a fire ignition can be directly attributed to ROW fuel hazards. Given these concerns, quantifying risk is an appropriate method to employ for the prioritization of areas for fuel reduction treatment. To this end, B.A. Blackwell and Associates Ltd. began a project, in 2003, to develop a Wildfire Risk Management System (WRMS) for BCTC ROW across the province of British Columbia. It is intended that the development of the Wildfire Threat Management System will address the following:

1. Provide a foundation for the development of a risk management zonation strategy;
2. Provide a framework on which to assess and prioritize fuel hazards;
3. Promote the development of new guidelines for vegetation management on the ROW;
4. Promote the development of new methods and techniques for fuel reduction;
5. Promote reduction of fire risk to critical infrastructure;
6. Support public communication and education of fire risk; and
7. Support interagency planning and cooperation in the development of fire management strategies.

For safety and efficiency reasons, vegetation in ROWs must be maintained at a height where it will not interfere with transmission lines. Manual slashing, mowing, and herbicides are employed as the standard vegetation management techniques for maintenance of BC ROWs. Organic waste from these treatments has generally been left on site. The advantage of methods, such as slashing, are speed and relatively low cost, particularly if slash can be left on site to decay. Since the 2003 fire season it has become clear that, in some parts of the ROW system, this waste poses a fuel hazard that is no longer acceptable. However, due to the amount of area covered by transmission corridors throughout the province (over 75,000 ha, which is equivalent to approximately 11,000 kilometers of right-of-way), it has not been easy to identify and prioritize areas for remedial treatment of the existing fuels on the ground. The WRMS system, in combination with an overview fuel survey, will be utilized to systematically identify priority fuel treatment areas.

Hand slashing using chainsaws is the major cause of fuel build-up on BCTC ROWs. The slash generally consists of large pieces and these accumulate over time with successive treatments. Due to their size, slash pieces may be elevated above the ground where they are slower to decompose and can act as ladder fuels that contribute to more extreme fire behavior. In addition, coppicing deciduous species will tend to produce more stems following slashing treatment so that the amount of debris left on the ground increases with each subsequent treatment. Mowing can be a more desirable treatment than slashing because it produces debris of a smaller size that sits in closer contact with the ground and decomposes more rapidly than slash. However, the cost of mowing is generally higher and mowing can only be undertaken on sites where there is road access for machinery, the slope is less than 30%, and on non-rocky sites where mowing heads will not be damaged. Areas identified by the WRMS and fuel survey as high priority for fuel treatments will be allocated additional funds to undertake mowing where feasible. Where mowing is not possible, resources will be directed towards debris management techniques such as pile and burn, bucking, and disruption of continuous fuel distribution.

WILDFIRE RISK MANAGEMENT

Wildfire threat analysis – the predecessor to WRMS – was initially pioneered in Australia (Muller, 1993; Vodopier and Haswell, 1995). The approach was adapted for use in British Columbia (BC), Canada, and has since been applied in a number of different contexts and scales (Hawkes and Beck, 1997; Blackwell et al., 2004). In all applications, the final output of a wildfire threat analysis is a map overlay that is intended to provide a spatial representation of all the critical factors that affect wildfire risk.

Advances in GIS capability and the adoption of more refined risk management techniques have contributed to an ongoing evolution of the original wildfire threat analysis methodology. In 2002, we collaborated on a significant advancement in GIS-based wildfire risk management modeling (Ohlson et al., 2003). As described further below, highlights of the wildfire risk management approach incorporated into this current application include the following:

1. The capability to spatially analyze and overlay separate and distinct wildfire risk probability and consequence ratings to support both strategic and tactical decision-making;
2. The development of a transparent and flexible system framework for encoding and manipulating all model inputs; and

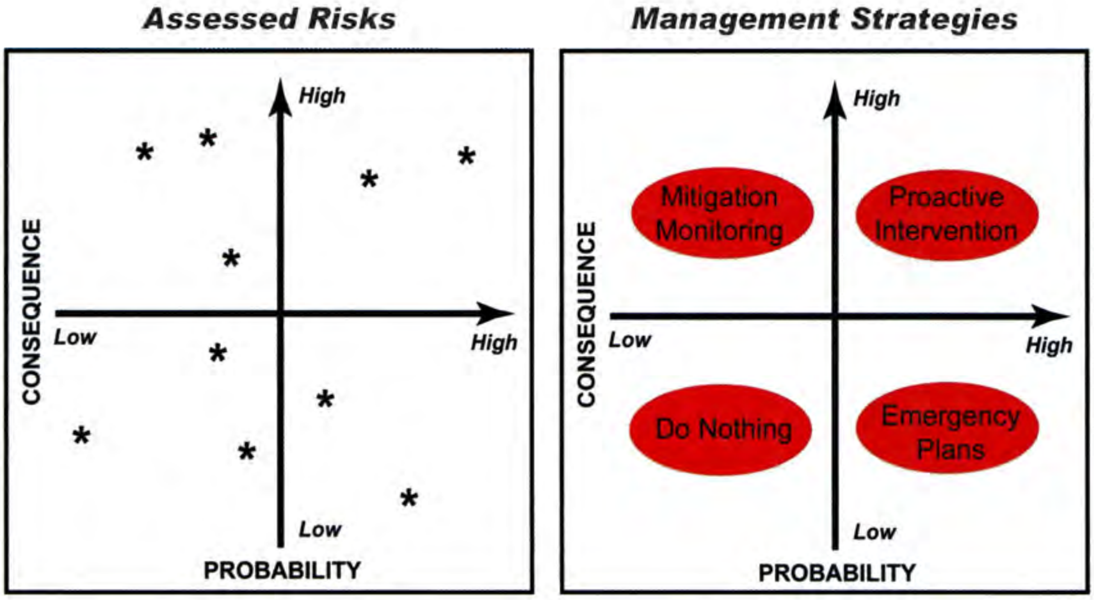

Fig. 1. Conceptual representation of risk assessment/management as the resultant of two factors, Probability and Consequence.

3. Establishing the basis for a dynamic user interface, which would enable multi-run, scenario planning, and sensitivity analysis capabilities.

Definitions of the term "risk" and all its derivatives (i.e., risk management, risk assessment, risk evaluation) are inconsistent in the wildfire literature, perhaps as a legacy of the fact that most wildfire research has been broken down into specialty topics such as fire behaviour, fire effects, and fire history/occurrence. For purposes of this project, we define wildfire risk as the probability and consequence of wildfire at a specified location under specified conditions. This definition, which emphasizes the measurement of risk in terms of the two components probability and consequence, is consistent with the generic definition of risk and its derivative terms being adopted in many jurisdictions worldwide (Canadian Standards Association, 1997; Council of Standards Australia/New Zealand, 1999; International Standards Organization, 2002).

Analytically, our approach to wildfire risk assessment provides a spatial characterization of risk based on probability and consequence. In simple terms, we want to know at any given location and at any given time, what is the probability of wildfire occurring, and what are the potential consequences (for a given wildfire behaviour) on valued resources.

In other fields of risk management (e.g., hazardous materials management), a single resultant quantification of probability and consequence is often derived mathematically. However, in the case of wildfire risk assessment we find (as in Bachmann and Allgower, 1998) that it is more useful to keep these elements separate, since they may imply different management approaches spatially. Conceptually, Fig. 1 shows how the various combinations of probability and consequence across the landscape can imply the basic management strategies. In practice, as shown in our application below, the implementation of this risk management approach requires a detailed spatial examination of assessment results across a full continuum from low to high ratings.

THE BCTC RIGHTS-OF-WAY

The BCTC manages 75,000 ha of rights-of-way throughout the province. Figure 2 shows the network of ROW and the buffered area (five kilometers on either side of the ROW) surrounding them that was included as part of the WRMS study area.

Wildfire is a natural disturbance agent in British Columbia. Historically, many areas of the province are adapted to particular fire regimes meaning that fire is a regular and natural occurrence in the environment. The probability of wildfire occurring in the area of BCTC power lines will vary depending on a number of factors. For the purposes of the WRMS the probability of a catastrophic fire is a function of ignition, fire behaviour, and suppression capability. However, prioritizing areas for treatment depends, not just on probability of a fire event, but the consequences of that event occurring. Wildland urban interface values (structure density), biological values, community watersheds, and timber supply are all important values that must be considered in a wildfire risk assessment of the BCTC ROW.

Fire management within and around the ROW, in keeping with the rest of the Province, has historically focused on initial attack and all wildfires have been actively suppressed. In some dry forest ecosystems within the province long-term suppression has resulted in fuel buildups and has been found to be an

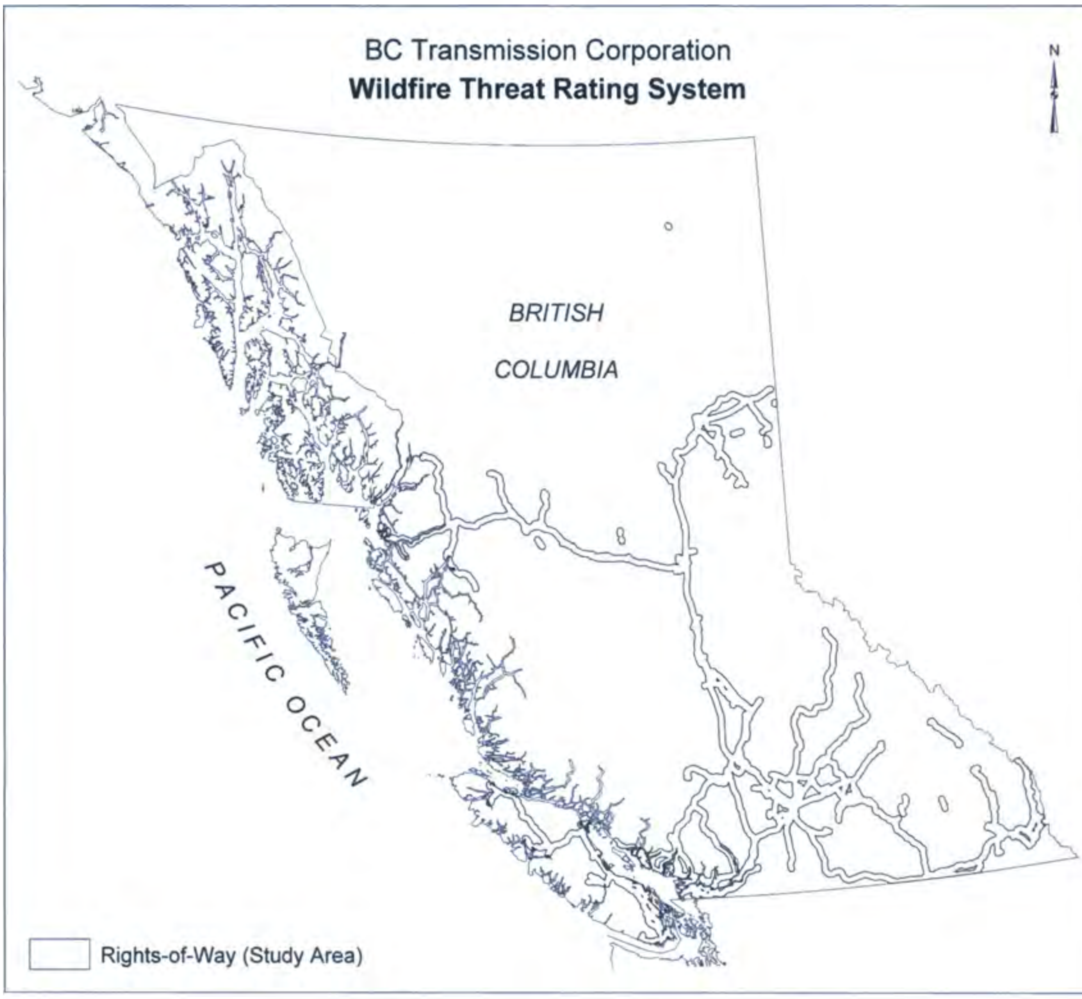

Fig. 2. Overview of BCTC rights-of-way.

inappropriate strategy for forest and ecosystem management (Blackwell et al., 2003). Fuel build-ups have resulted in increased fire severity and losses of important ecosystem structure and function. Although the BCTC ROW system is designed with the purpose of transmitting power safely and efficiently and cannot be regarded as a 'natural' ecosystem, protection of ecosystems that border the transmission corridor is important to BCTC. Overall, it is desirable to reduce the probability of wildfire occurring in ROW; however, where and when to focus resources to reduce wildfire probability depend upon the consequences of the impact. Accordingly, the specific wildfire risk management issues that need to be addressed or supported by the WRMS are the following:

1. To evaluate ROW fire risk to identified resource values adjacent to the BCTC network;
2. To support strategies that limit the impacts of fire on the BCTC infrastructure;
3. To support the priorization of risk reduction strategies associated with vegetation management; and
4. To support an effective, multi-agency approach to wildfire preparedness planning.

METHODS

Our goal was to develop a spatial representation of all factors that influenced the probability and consequences of wildfire in the BCTC Rights-of-Way. The basic model structure was based on a previous WRMS application as described in Ohlson et al. (2003). The WRMS for the BCTC ROW was developed through a series of workshops that involved BCTC staff and fire management specialists from B.A. Blackwell and Associates Ltd. The model is implemented in a GIS environment using ArcMap 8.2.1 (™ESRI) and ArcInfo 8.0.2 (™ESRI) using a raster grid at 50 m by 50 m cell resolution.

The final WRMS model structure for BCTC is portrayed in Fig. 3. The final spatial probability rating is derived from three major components: Ignition Probability, Fire Behaviour, and Suppression Response Capability.

The final spatial consequence rating is derived from four major components that are significant within the BCTC Rights-of-Way: Interface, Biological Values, Timber Values and Watersheds. Each main model compo-

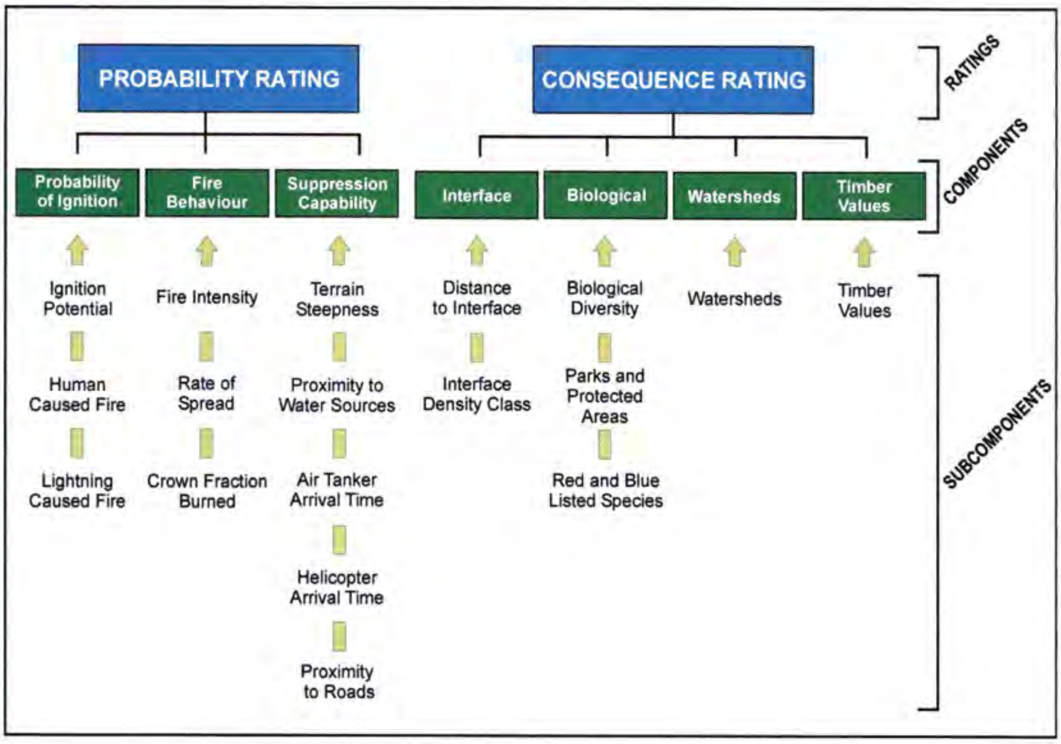

Fig. 3. BCTC Wildfire Risk Management System (WRMS) Model Structure.

Table 1. Overview of methods and sub-models for each subcomponent of the BCTC Wildfire Risk Management System

	Component	Subcomponent	Overview method
Probability Rating	Probability of Ignition	Ignition Potential	Calculation based on fuel type and fire weather indices
		Lightning Caused Fire	Inverse distance weighted interpolation of the number of lightning fire ignition points (since 1950) within a 500 m buffer
		Human Caused Fire	Inverse distance weighted interpolation of the number of human fire ignition points (since 1950) within a 500 m buffer
	Fire Behaviour	Fire Intensity	Calculation using fire weather, fuel type and topography
		Rate of Spread	Calculation using fire weather, fuel type and topography
		Crown Fraction Burned	Calculation using fire weather, fuel type and topography
	Suppression Response Capability	Terrain Steepness	Average slope of forest inventory polygon
		Proximity to Water Sources	Buffer distance from determinant streams and lakes
		Helicopter Arrival Time	Measured flight time (concentric) from helicopter base
		Air Tanker Arrival Time	Measured flight time (concentric) from air tanker base
		Proximity to Roads/Helipads	Buffer distance from roads, helipads, and alpine tundra/parkland
Consequence Rating	Biological	Red & Blue Listed Elements	Areas containing red and/or blue listed species or ecosystems
		Biological Diversity	Age class
		Parks and Protected Areas	Presence of a Provincial Park or Protected Area
	Watershed	Proximity to Community Watersheds	Distance from community watersheds
	Timber Supply	Timber Supply	Volume
	Interface	Wildland Urban Interface Distance	Buffer distance from ROW to structures
		Wildland Urban Interface Density	Buffer distance from ROW to density classes (structures/km^2)

nent is in turn derived from several subcomponents as shown in Fig. 3.

At the subcomponent level, individual ratings for each raster cell are developed on 0–10 scales that are based on existing biophysical databases and in some cases the application of sub-models (e.g., rate of fire spread calculated using the Canadian Fire Behavior Prediction System and spatial fuel inventory data). An overview of each subcomponent method and/or sub-model is provided in Table 1.

At the component level, the rating for each raster cell is calculated as a weighted sum of all its subcomponents. Table 2 provides an example of the rating scales and subcomponent weighting for the Suppres-

Table 2. Component level rating example: suppression response capability

Attribute	Indicator/Units	Rating scale		Weight
Proximity to Water Sources	Distance (D) metres	>300	10	10%
Indicator of the ability to access water quickly for fire fighting.		101–300	7	
Small permanent streams and higher order from TRIM		0–100	2	
Helicopter Arrival Time	Minutes	>40	10	30%
Indicator of time for initial attack, measured as flight time		31–40	7	
(concentric) from primary bases		21–30	5	
		11–20	3	
		0–10	0	
Air Tanker Arrival Time	Minutes	>40	10	30%
Indicator of time for air tanker action measured as flight time		31–40	7	
(concentric) from primary bases		21–30	5	
		11–20	3	
		0–10	0	
Terrain Steepness	Slope Class %	>60	10	10%
Indicator of the difficulty of control/contain on the landscape		41–60	7	
		21–40	3	
		0–20	0	
Proximity to Roads	Minutes	>120	10	10%
Indicator of the ability to get suppression resources into an area:		61–120	7	
based on a bush walking rate of 1 km/hour		31–60	5	
		16–30	3	
		0–15	0	

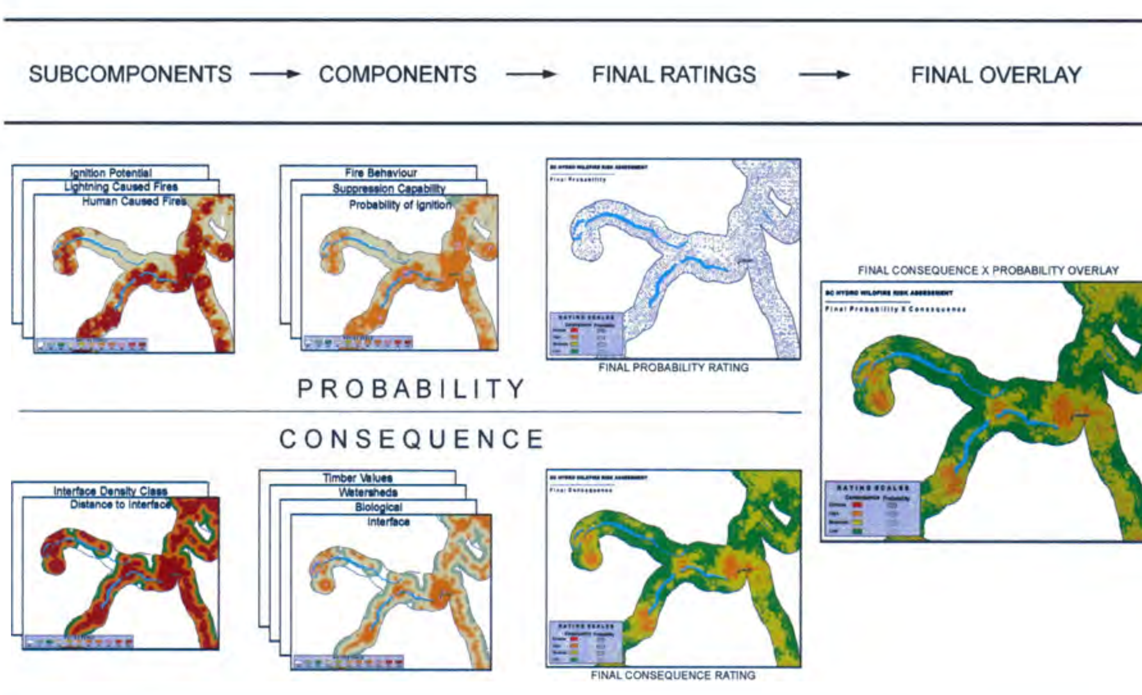

Fig. 4. Summary mapping outputs from the BCTC Wildfire Risk Management System.

sion Response Capability component. All other components are derived in a similar manner. Similarly, at the overall rating level for probability or consequences, the rating for each raster cell is calculated as a weighted sum of all its components.

RESULTS AND DISCUSSION

Figure 4 presents a compilation of mapping outputs from the initial implementation of the BCTC WRMS. The resultant mapping outputs parallel the structure of the model as described in the previous section, i.e.,

1. Subcomponents maps are generated using 0–10 rating scales derived from existing GIS databases and/or sub-model outputs;
2. Component maps are generated using user-defined weights on each subcomponent layer;
3. Final probability and consequence rating maps are generated using user-defined weights on each component layer; and
4. A final probability – consequence overlay map is generated by overlaying the final rating maps.

As previously discussed, the consequences of importance identified for this analysis are the wildland urban interface, community watersheds, biological values and timber supply. The consequence ratings depend on the spatial location of the ROW in relation to these values. The probability ratings depend on the probability of ignition, fire behaviour and suppression. In terms of wildfire probability, there is a relatively large area (90%) of moderate to high rating throughout the ROW network. These probability ratings are driven largely by terrain steepness and its effect on fire behaviour and suppression response capability. Gaining a better understanding of the spatial interaction between probability and consequence ratings is core to the development of appropriate risk management interventions. Obvious areas for immediate fuels management treatments are those with both high probability and consequence ratings. Less obvious are those areas with lower probability, yet high overall consequence ratings, or a very high consequence rating for a single value such as community watershed protection. In this case, the WRMS provides the basis for improved dialogue (and technical assessment) with resource managers on adjacent lands toward the purpose of developing more detailed risk management strategies. However, because of their important contribution to risk ratings, justification for selecting these consequence values is provided in the following paragraphs.

In overview, the area of highest consequence (8% rated as high or extreme) is located in close proximity to interface communities and community watersheds. These are the areas of highest value in terms of public safety and property protection. Fire occurrence in interface areas is of obvious concern due to the density of people, housing and infrastructure existing in those areas and the high costs associated with their destruction. Community watersheds are also of particular importance because 86% of BC's population acquires its drinking water from surface water (Cameron et al., 2000). As of 2000, there were a total of 12,000 watersheds licensed under the Water Act comprising, in total, 1.2% of the area of BC (Cameron et al., 2000). Because most of these watersheds supply drinking water that is only minimally treated it is necessary to limit any impact on raw water quality (Cameron et al., 2000). Wildfire tends to have negative effects on drinking water quality through removal of ground vegetation cover and subsequent fire related flooding, increased sediment loading and inputs of woody debris (Bisson et al., 2003). Although the long-term effects of fire on aquatic communities can be positive through improvements to the health of the surrounding terrestrial ecosystem (Bisson et al., 2003) the short-term impacts on drinking water have negative health impacts on the population that is dependant on that source. Maintaining the quality of source water is the most effective way to provide cheap and safe drinking water without requiring the construction of expensive treatment plants at a high cost to the community. Therefore, it can be argued that reducing the probability of catastrophic wildfire in terms of its consequence on drinking water values is justified. The WRMS provides watershed managers with a formal means of evaluating annual investments in different vegetation management treatments and standards of practice. Different investment levels can be evaluated in terms of their ultimate effect on the ROW network risk profile and, ultimately, wildfire probability in a spatially explicit way.

The ROW transects productive forestland that is critical to the stability of many rural B.C. communities. The impacts of a large fire in these areas could be devastating to community stability in the aftermath of the fire and for many years to come. Communities tend to interact with forest areas in complex ways, in that it is not just the timber and tourism industries that are affected when the forest is disrupted. Impacts are likely to include loss of economic stability through loss of direct and indirect forest income and employment. There may also be social impacts such as loss of population, social services, citizen participation and commitment to place (Pierce and Roseland, 2000) that can lead to community instability. It is these concerns that support the argument for reducing the risk of wildfire in ROW that are adjacent to timber supply and, depending on management objectives, parks and protected areas. British Columbia has a world-class system of parks and protected areas, and is a world leader in biodiversity and ecosystem management. The protection of these values is critical to the citizens of the province and has contributed to risk values in ROW adjacent to parks and protected areas.

The WRMS is being used to aid management decisions in several ways. Based on the probability and consequence outputs, the priority management zones in the ROW network are being developed in terms of risk management and mitigation strategies. These management zones will aid budgeting and prioritization of fuel hazard abatement programs making the decision process more transparent and efficient. Vegetation management standards are being revised in identified areas of high risk to reduce fuel hazards associated with traditional slashing practices. The WRMS maps can also be used to identify infrastructure that is vulnerable to fire and take steps to reduce wildfire risk in particular locations. In addition, the WRMS system has application as a tool to increase public confidence through educating and communicating actions being taken by BCTC to address wildfire risk. It is also being used to communicate the corporate wildfire risk profile within and outside of the corporation. The system provides a spatial quantification of corporate liability associated with fire.

Applying WRMS to transmission ROW is a unique approach because of the spatial distribution and function of the area under analysis. The risk rating is largely concerned with the impact of fire on values identified outside the ROW, although loss of transmission line is intrinsically accounted for through risk reduction within the ROW. Adjacency issues are a general concern when conducting fire risk management for other areas, such as provincial parks, but generally, due to the shape of the area, there is little impact on consequence ratings. However, any fire that starts in a ROW is likely to impact an adjacent area and so the values that surround the ROW will be significant in deriving the consequence rating. Because BCTC must consider the consequences of wildfire to resources adjacent to its ROW, the WRMS facilitates cooperation with other resource agencies, including the B.C. Ministry of Forests, Ministry of Water, Land, and Air Protection, and Ministry of Sustainable Resource Management, and provides a foundation on which to base sound, sustainable, stewardship management principles. This type of application should be of interest to transmission system managers worldwide who are wrestling with the potential impacts of wildfire on important resource values.

CONCLUSIONS

The 2003 fire season in B.C. was a wake up call for resource managers in many parts of British Columbia including those responsible for the transmission of electrical power. It is intended that this WRMS tool provide a foundation on which to develop a proactive and preventative approach to wildfire management so that extensive damage and downtime in the BCTC transmission system can be avoided.

In summary, we believe the BCTC Wildfire Risk Management System provides an increased capacity to make sound and defensible wildfire management decisions, to protect the infrastructure network and the wildland–urban interface, where planning requirements are the most challenging. The ability to spatially analyze and overlay probability and consequence ratings can support both strategic and tactical decision-making regarding hazard abatement, vegetation management, and vulnerability assessment of important assets and infrastructure.

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REFERENCES

Bachmann, A. and B. Allgower. 1998. A framework for Wildfire Risk Analysis. In: Proceedings of the III International Conference on Forest Fire Research, 14th Conference on Fire and Forest Meteorology. Coimbra, Portugal. Vol. 2, pp. 2177–2190.

Bisson, P.A., B.E. Rieman, C. Luce, P.F. Hessburg, D.C. Lee, J.L. Kershner, G.H. Reeves, and R.E. Gresswell. 2003. Fire and Aquatic Ecosystems of the Western USA: Current Knowledge and Key Questions. Forest Ecology and Management, 178: 213–229.

Blackwell, B.A., R.W. Gray, F.M. Steele, A.J. Needoba, R.N. Green, and K. MacKenzie. 2004. A wildfire threat rating system for the Birkenhead and Gates Landscape Units, British Columbia. In: R.T. Engstrom and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Blackwell, B.A., R.W. Gray, R.N. Green, F.F. Figel, T.M. Berry, D.W. Ohlson, and B. Hawkes. 2003. Development and implementation of a regional scale assessment of forest fuel conditions in southern British Columbia. Manuscript under review.

Canadian Standards Association. 1997. Risk Management: Guideline for Decision-Makers: A National Standard of Canada. CAN/CSA-Q850-97. Etobicoke, Canada.

Cameron, V.Z., P. Geo, R. Kreye, and B. Kangasniemi. 2000. Source Water Protection for British Columbia's Community Watersheds: An Evolving Model. http://www.alternatives.com/bctwa/WS2000Abstract.htm

Council of Standards Australia/Council of Standards New Zealand. 1999. Risk Management. AS/NZS 4360:1999. Strathfield, Australia.

Filmon, G. 2004. Firestorm 2003 Provincial Review. http://www.for.gov.bc.ca/protect/reports/2003Review/Protection_Submission_to_Filmon.pdf

Gollberg, G.E., L.F. Neuenschwander, and K.C. Ryan. 2001. Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management. *International Journal of Wildland Fire*. Special Issue Volume, 10: 263–265.

Green, R.N., B.A. Blackwell, K. Klinka, and J. Dobry. 1999. Partial reconstruction of fire history in the Capilano watershed. Chapter 12 in Greater Vancouver Regional District watershed ecological inventory program: Annex: Analysis reports watershed management plan No. 5.

Hawkes, B. and J. Beck. 1997. A wildfire threat rating system. 1997. Forest Service, Pacific Forestry Centre, Victoria, BC. Technology Transfer Note 01.

International Standards Organization. 2002. Risk Management Vocabulary, Guidelines for use in Standards. First Edition. ISO/IEC Guide 73:2002(E/F). Geneva, Switzerland.

Muller, C. 1993. Wildfire threat analysis: A decision support system for improved fire management. Paper presented at "The Burning Question: Fire Management in NSW," Coffs Harbour, Aug. 1993, UNE, Armidale, NSW, Australia.

Ohlson, D.W., B.A. Blackwell, B.C. Hawkes, and D. Bonin. 2003. A Wildfire Risk Management System – An Evolution of the Wildfire Threat Rating System. 3rd International Wildland Fire Conference Proceedings. Sydney, Australia, October 2003.

Pierce, J.T., M. Roseland. 2000. Promoting Community Economic Development for Forest-Based Communities; Final Report. CED for

Forest-Based Communities. Simon Fraser University Community Economic Development Centre, BC, Canada. http://www.sfu.ca/cscd/forestcomm/reports/cedcforestcommrpt31.pdf

Salazar, L.A. and C.V. Nilsson. 1989. Integrating geographic information systems into fire management. Proceedings 10th Conference on Fire and Meteorology. Ottawa, Ontario.

Standards Australia. 1999. Risk Management Standard. AZ/NZS 4360:1999. Standards Association of Australia. Strathfield, Australia.

Vodopier, J. and D. Haswell. 1995. The application of wildfire threat analysis in forests of southwestern Australia. In: BUSHFIRE '95, Australian Bushfire Conference, Sept. 27–30, 1995, Hobart, Tasmania.

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Fiona has worked for B.A. Blackwell & Associates Ltd. since 1996 where she has constructed several wildfire risk management systems in British Columbia and Alberta. Additionally she has been involved in GIS mapping and analysis, ecosystem classification, and vegetation and historical stand structure studies. She has a Bachelor of Science in Forestry from the University of British Columbia.

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Trained as both a professional environmental planner and engineer, Dan works on environmental risk management problems that involve multiple resource use conflicts, scientific uncertainty, and environmental and economic trade-off analyses. He has developed several resource valuation methods and models for wildfire management, climate adaptation, and habitat restoration, and he has designed and facilitated numerous training seminars, planning processes and expert workshops across a wide variety of sectors.

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Amelia has recently re-joined B.A. Blackwell & Associates Ltd. as a forestry graduate. She has been involved in GIS mapping and analysis, vegetation and historical stand structure studies and fuel studies. She has a Bachelor of Science and a Bachelor of Forest Science from the University of Melbourne.

Part XV
Restoration

Restoration on a Pipeline Right-of-Way in Red Rock Canyon National Conservation Area, Nevada

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Construction of the nearly 720-mile Kern River 2003 Expansion Project (Project) from Wyoming to California involved crossing approximately 5.4 miles of the Red Rock Canyon National Conservation Area and 0.9 miles of the Spring Mountain National Recreation Area in Nevada. These special use areas were established since the original system was constructed in 1991. More intensive restoration treatments were necessary with the goal of eliminating residual impacts to promote the scenic, cultural, and biodiversity values of this special use area. Moreover, it was necessary for a net benefit to be demonstrated for the Bureau of Land Management (BLM) to amend the original Grant of right-of-way (ROW). To demonstrate net benefit, the Kern River Gas Transmission Company (KRGT) designed and implemented more intensive revegetation efforts than required for other segments of the ROW. These measures included: field consultation with BLM and other stakeholders, baseline vegetation surveys; salvage of both succulent and non-succulent shrubs; replanting additional locally available plant materials; topsoil segregation; recontouring of the land surface utilizing rock salvaged from land clearing and trench excavation and placed in such a manner as to enhance visual aesthetics; direct seeding with native species; trial use of specialized/pelletized seed; and, off-highway vehicle (OHV) controls. These treatments were also applied on the adjacent existing ROW. A 6-year monitoring program was developed with the success criteria being to reach 80 percent plant cover, density and richness of native vegetation compared to representative off-ROW reference plots. Findings from monitoring in the summer of 2004 are presented, and also include transplantings done on the existing ROW in the more recently established Mojave National Preserve in California.

Keywords: Bureau of Land Management (BLM), desert restoration, Kern River Gas Transmission Company (KRGT), off-highway vehicle (OHV) control, revegetation, monitoring, right-of-way (ROW), stakeholders, visual resources

INTRODUCTION

The Kern River 2003 Expansion Project was the first major natural gas project recently approved and constructed under a more fast-track Federal Energy Regulatory Commission (FERC) 7(c) certification and permitting process. In general, this process is similar in concept to the voluntary FERC pre-filing process currently in use on a number of projects, for which formal guidance and requirements have since been developed by the FERC and cooperating agencies. In order to facilitate more expedited review and approval of the Project, Williams Gas Pipeline (WGP) and Kern River Gas Transmission Company (KRGT) entered into pre-filing consultation with a number of federal and state agencies on issues including restoration of the right-of-way (ROW) and cultural resources. Where the ROW crossed particularly sensitive areas such as the Red Rock Canyon National Conservation Area (NCA) and the Spring Mountain National Recreation Area (NRA) in Nevada, WGP and KRGT designed and implemented an extensive set of proven and innovative restoration methods that serve to restore the ROW to earlier conditions and ensure that the project has a net positive affect on the surrounding area. KRGT also applied restoration methods on the existing KRGT ROW that was constructed through what is now the Mojave National Preserve in California. The Restoration plans

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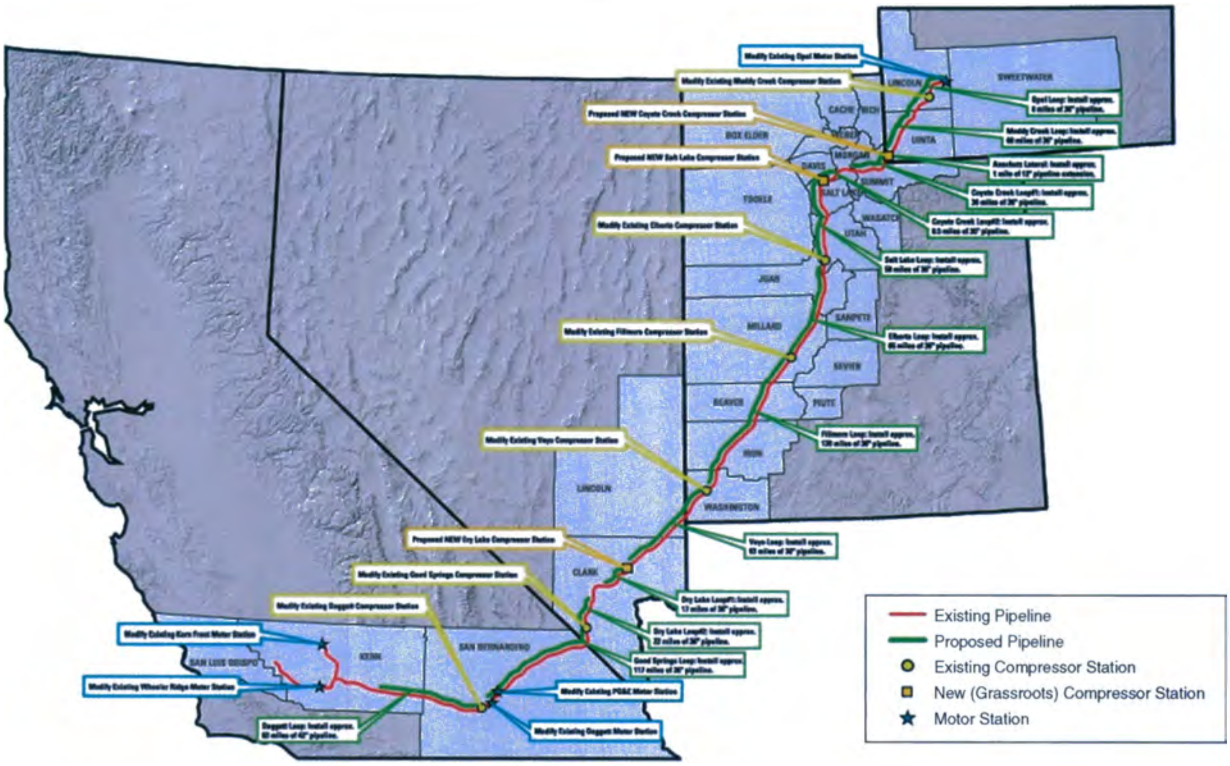

Fig. 1. Location of Kern River 2003 Expansion Project Facilities.

were developed, reviewed and approved prior to issuance of the Final Environmental Impact Statement (FEIS).

PROJECT DESCRIPTION

Kern River 2003 Expansion Project

KRGT completed the expansion of its interstate natural gas pipeline system in May of 2003. The expansion, known as the Kern River 2003 Expansion Project (the Project), extends from southwestern Wyoming to southern California. It involved the construction of approximately 720 miles of 36 and 42-inch diameter pipeline loops along the existing mainline, including 69.3 miles in Wyoming; 341.4 miles in Utah; 120.6 miles in Nevada; 104.0 miles on the Mainline in California; 82.2 miles on the Common System (California); and an 0.8-mile, 12-inch diameter pipeline lateral extension in Uinta County, Wyoming. The Project also included construction of 3 new compressor stations in Wyoming, Utah and Nevada; modifications to 6 existing compressor stations in all 4 states; modifications to meter stations in Wyoming and California; 24 pig launcher/receiver facilities and 55 mainline valves (Fig. 1).

Except where required by topography, land use, presence of other utilities, or other constraints the pipeline loops were laid at a typical 25-foot offset from the existing pipe centerline utilizing a 75- to 90-foot construction ROW with additional temporary work space (ATWS) where required for road and railway crossings, streams and washes, side hills, and other limiting features. Launcher/receiver facilities and mainline valves were constructed within the fence lines of or adjacent to other aboveground facilities to the extent feasible to minimize impacts. Construction activity was restricted to the environmentally inventoried and surveyed corridor from surveys completed in 2001 and additional surveys conducted immediately prior to construction by biological monitors and accepted as variances to the construction permit by regulatory agencies.

Crossing of protected areas

Construction of the Project involved crossing approximately 5.4 miles of the Red Rock Canyon NCA and 0.9 miles of the Spring Mountain NRA in Clark County, Nevada (Fig. 2). In addition, the existing ROW crossed the Mojave National Preserve in San Bernardino County, California and construction for the expansion required use of recreational roads leading into the Mojave National Preserve (Fig. 3).

The Red Rock Canyon Recreation Lands were designated as a NCA by an Act of Congress in 1990 in an effort to increase protection of the area. The original KRGT mainline pipeline system constructed in 1990 and 1991 did not cross the NCA boundaries in place at the time. However, in 1994, the NCA boundaries were expanded to protect additional land resources to the north and south, thereby enveloping the mainline pipeline ROW.

The Red Rock Canyon NCA now encompasses 197,000 acres and is located 10 miles west of Las

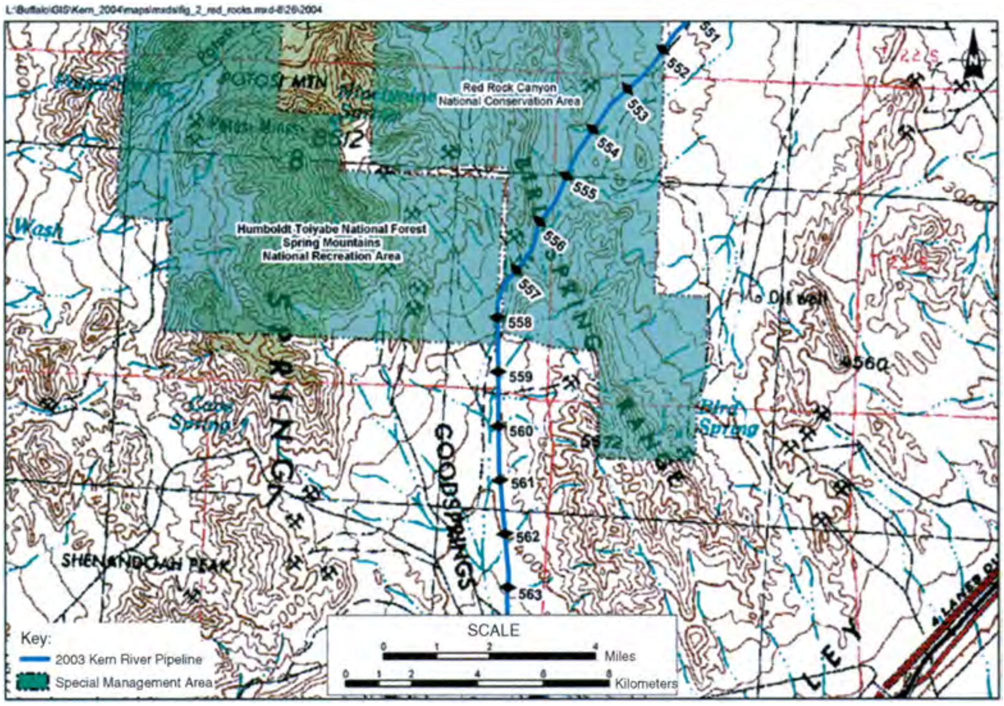

Fig. 2. Location of KRGT ROW crossing of the Red Rock Canyon NCA and Spring Mountain NRA in Nevada.

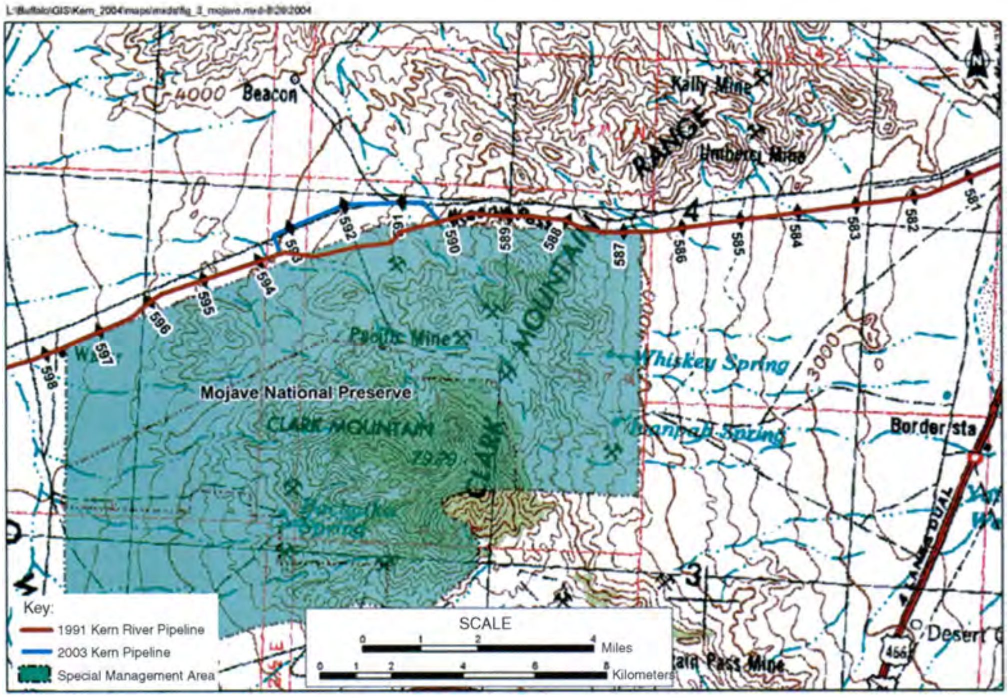

Fig. 3. Location of existing KRGT ROW crossing Mojave National Preserve in California.

Vegas, Nevada on the eastern slope of the Spring Mountains and is managed by the Bureau of Land Management (BLM). The NCA provides numerous recreational activities to Las Vegas residents and other visitors, including: backpacking and camping, rock climbing, bicycling, and naturalist-guided walks. Visitors also enjoy 30 miles of hiking trails, a 13-mile scenic drive, educational programs, a visitor center, and picnic areas. The pipeline ROW crosses a motorized vehicle restriction area and trails associated with the Cottonwood Valley Trail System that are used for mountain biking, horseback riding, and hiking (FERC, 2002). Requirements for a motorized vehicle restriction area are, as follows:

- Area(s) may not necessarily be remote and access may be easy, but human interaction would be low;
- Opportunities provided could include trails for mountain bikers, horse riders, and hikers;

- Existing roads closed and converted to trails, motorized use is prohibited;
- Off-site controls preferred; and
- New Facilities are to be avoided, but may be provided for resource protection or use safety (FERC, 2002).

In addition to crossing a motorized vehicle restriction area, the pipeline ROW traverses visually sensitive areas. The ROW can be seen from the Boarder of the Humboldt-Toiyabe National Forest and Red Rock Canyon NCA, Cottonwood Valley Trail Access Road (from Nevada Highway 160). An overlook gives a northeastern view of Las Vegas having a Visual Resource Management designation of Class II. These areas are designated as having a high level of scenic quality and sensitivity, where landscape changes can be seen, but should remain subordinate to the characteristic landscape. Visual Resource Class II areas should also not attract attention from the casual observer.

Humboldt-Toiyabe National Forest/Spring Mountains National Recreation Area

After crossing the Red Rock Canyon NCA, the Project crosses the Spring Mountains NRA. As with the Red Rock Canyon NCA, the Humboldt-Toiyabe National Forest/Spring Mountain Area was not designated as a NRA until August 1993, after the construction of the original pipeline.

The Spring Mountains NRA encompasses more than 316,000 acres and is part of the Humboldt-Toiyabe National Forest west of Las Vegas (USFS, 2004). Recreation opportunities include hiking, camping, climbing, skiing, sightseeing, and bird-watching. The pipeline route crosses Management Area 13, where the United States Forest Service (USFS) is providing increased levels of recreation development and services and increased multi-use trails and campsites (FERC, 2002).

Mojave National Preserve

As with the areas discussed above, the original KRGT pipeline ROW was constructed across a sensitive area before it was designated for formal protection. The existing KRGT pipeline crosses the Mojave National Preserve just inside the northern boundary of the preserve, which was designated in 1994 as a national preserve and placed under National Park Service (NPS) jurisdiction after the installation of the original KRGT pipeline.

In response to comments from the NPS, KRGT routed the Project loop outside the boundaries of the Mojave National Preserve and within a designated utility corridor. In addition, KRGT agreed to leave at least three of the access roads into the preserve open during construction so as to maintain public access for established recreational purposes. During restoration, KRGT further coordinated with the NPS and made additional plantings of salvaged plant materials onto the existing ROW in the more recently-established Mojave National Preserve in order to enhance this original segment of the ROW for visual resources and wildlife habitat, and in order to discourage off-highway vehicle (OHV) use of the original pipeline ROW.

REGULATORY CONTEXT

As part of the overall permitting and approval of the Project, KRGT was required to obtain amendments to the original Grant of ROW for federal lands from the BLM as the lead agency. Given the importance of the natural setting, recreation activities, and the visual aesthetics of the Red Rock Canyon NCA and the Spring Mountains NRA, restoration of the ROW was deemed of utmost importance for obtaining approval for the Project through these areas. More intensive restoration treatments were necessary with the goal of eliminating residual impacts to promote the scenic, cultural, and biodiversity values of these special use areas and the Mojave Preserve. Moreover, it was necessary for a net benefit to be demonstrated in order for the BLM to amend the original Grant of ROW for looping along the existing pipeline through these special use areas. If a net benefit were not demonstrated, KRGT may have been required to use alternative routes; obtain approvals for additional ROW, subject to an amendment approved by the U.S. Congress; and/or request that the BLM revise the existing Las Vegas District Resource Management Plan to authorize the Project as a specific exception on lands designated as national conservation areas.

Route selection and design

Alternative Alignment

Because of the sensitivity of Red Rock Canyon NCA, Spring Mountains NRA, and the Mojave Preserve, the FERC requested that KRGT evaluate avoidance of these areas. To satisfy this request, KRGT conducted an environmental, engineering, and economic analysis of a route alternative that would have avoided crossing these areas. As mentioned above, KRGT routed the expansion pipeline loop outside the boundaries of the Mojave National Preserve and within a designated utility corridor. Additionally, the Red Rock Canyon Alternative Alignment was estimated to increase the length of the pipeline by 2.54 miles at an additional cost of $3.8 million. This alternative would have created a new utility corridor for a distance of 16.18 miles in order to avoid 5.33 miles of BLM special use area lands and 0.6 miles of USFS lands. It was determined that the alternative alignment would have increased operations and maintenance costs associated with non-collocated loop segments, likely increased costs for desert tortoise mitigation, and created a new visual disturbance in an otherwise undisturbed area. Based on this analysis, it was concluded that collocating the new loop along the existing pipeline corridor through the NCA was preferable, if an overall net benefit could be demonstrated and approved by the BLM and other stakeholders.

Removal of loop

KRGT also evaluated the feasibility of removing the 36-inch loop from the system design through this area. Due to the proximity of these areas to the intake side of the existing Goodsprings Compressor Station, removing the portion of the loop would have caused the suction pressure at Goodsprings to drop significantly, which would have required the further addition of a turbine and result in increased air emissions, increased project cost to KRGT and the rate payers, additional aboveground structures, and decreased efficiency and reliability of the pipeline for delivery of the subscribed natural gas volumes to customers in California. Based on these evaluations, it was determined that KRGT's preferred design would be to route and construct the new loop parallel to the existing pipeline, and maximize overlap of the existing ROW and previously disturbed areas through these areas.

Reduced right-of-way width

To minimize impacts to previously undisturbed areas, the Project loop was constructed 20-feet from the existing pipeline where possible through the NCA and immediately adjacent to the existing ROW through the NRA. This was done so that the new 36-inch diameter pipeline loop for the Project could lie entirely within the boundary of the originally permitted 50-foot ROW. No above-ground facilities or new access roads were constructed in 2003, although some modifications were made to existing roads within the NCA. This alignment minimized impacts to previously undisturbed vegetation and other resources, and maximized use of previously disturbed areas. The effectiveness of economizing wherever possible on ROW width is readily illustrated by actual acreages disturbed determined after construction. Of the 79.9 acres of total construction disturbance, only 15.7 acres were newly disturbed, with the remaining acres in areas that were previously disturbed.

BLM requirements

In addition to reducing the construction and operation ROW widths, KRGT was required to implement special restoration measures. KRGT developed general reclamation treatments and selected site-specific techniques beginning with the Reclamation Plan developed for the existing KRGT Mainline pipeline (Dames & Moore, Inc., 1990). The original reclamation plans were distributed to the agency representatives early in the permitting and approval process, before the FERC 7(c) or state applications were submitted. KRGT requested input on the effectiveness of the original measures and recommendations for improvements based on current conditions on the ROW and more recent technical experience. Of particular importance were the following plans developed under the lead of the BLM Las Vegas Field Office: the *Draft Restoration Plan for Energy Projects* (BLM, September 2001) and *Draft Restoration Success Standards and Monitoring Plan* (BLM, November 2001). The BLM plans address general restoration for a number of planned or future energy and related development projects, in order to provide consistent restoration standards and requirements and minimize the cumulative effects of these planned or future projects concentrated in the region. In addition to using the BLM plans, KRGT also attended several meetings with the BLM, non-profit advocacy organizations, and the Natural Resources Conservation Service (NRCS) on the subject of restoration.

For the Red Rock Canyon NCA and Spring Mountain NRA, which were identified as requiring the highest levels (R-1) of treatment in the BLM *Draft Restoration Plan for Energy Projects*, KRGT implemented specific restoration methods, including field consultation with the BLM and other stakeholders; baseline vegetation surveys; salvage of perennial shrubs, succulents, vertical mulch and rocks; topsoil segregation; soil treatment; rock salvage and replacement to enhance visual restoration; direct seeding with native species; trial use of specialized/pelletized seed; OHV-controls; and provisions to apply Permeon™, an environmentally safe visual impact mitigation coating applied to disturbed rock. These methods are described below.

RESTORATION METHODS

A summary of the more intensive revegetation efforts designed and implemented by KRGT to reclaim project-related disturbances within the Red Rock Canyon NCA and Spring Mountain NRA is provided below.

Field consultation with BLM and Stakeholders

As mentioned above, KRGT utilized and adopted, where appropriate, restoration treatments, performance standards and monitoring protocols contained in the *Draft Restoration Plan for Energy Projects* developed by the BLM. KRGT also distributed the original Project Reclamation Plans to the BLM field offices in 2001 requesting review, comments, and recommendations to these Plans, in addition to contacting NRCS offices (E & E, 2002). To follow-up on these requests, KRGT met with BLM on November 8, 2001 and December 20, 2001 (meetings included representatives of the Resources Advisory Council, Audubon Society, and Sierra Club) to conduct field trips along the ROW and to discuss further development of this Plan (E & E, 2002). KRGT then met with the BLM in February 2002 to gather additional comments to the Reclamation Plans, and incorporate applicable revisions from the most recent and final draft of the *Restoration Plan for Energy Projects* (BLM, September 2001). Reclamation treatments and site-specific measures designed for the Project were updated based on input and comments from local experts and appropriate federal, state and local agencies, KRGT's experience during the original

Fig. 4. Field consultation with BLM and stakeholders on the Kern River 2003 Expansion Project.

construction, and were based largely on basic, proven, and accepted reclamation practices. In addition to the reclamation procedures and measures implemented on the ROW through the Mojave Desert, KRGT implemented additional specific reclamation treatment procedures on the ROW through Desert Tortoise Critical Habitat Areas, the Red Rock Canyon NCA and the Spring Mountain NRA.

The BLM and other stakeholders concluded that the application of these more intense restoration measures on the Project ROW, as well as on portions of the original ROW, through NCA and NRA lands would demonstrate a net benefit to amend the existing Grant of ROW, as opposed to avoiding these special use areas and establishing a new ROW for the loop to reach the Goodsprings Compressor Station.

While more intense restoration treatments were the primary means of demonstrating net positive benefit, including restoration of portions of the existing ROW that would not otherwise have been disturbed during construction, KRGT also agreed to some additional improvements suggested by BLM and the other stakeholders. To further demonstrate a net benefit of the Project, KRGT contributed $100,000 to the Las Vegas BLM general fund for the development of parking facilities, an informational kiosk, and water well development for the wild horse and burro program in the Red Rock Canyon NCA. Provisions were also made to provide temporary water sources to wild horses and burros during construction, to avoid concerns that the open trench, overburden and topsoil stockpiles, and general construction activity would interfere with the normal wild horse and burro movement patterns to existing springs and a wildlife guzzler maintained by the BLM.

Baseline vegetation surveys

As required by the FERC and other involved agencies, and prior to filing the Application for Article 7(c) certification, KRGT conducted comprehensive biological surveys to identify wetlands, streams, and dominant vegetative communities within the proposed ROW. In the Red Rock Canyon NCA and Spring Mountain NRA, all proposed access and staging areas and ATWS along the pipeline were surveyed and inventoried using a Geographical Information System (GIS) and aerial photography. Special status plants were also inventoried. In the Red Rock Canyon NCA, the yellow two-tone beardtongue (*Penstemon bicolor* ssp. *bicolor*) was the only sensitive plant species observed within the survey corridor during the 2001 field season. No other sensitive plants were identified.

KRGT, in cooperation with BLM, also conducted a baseline vegetation survey in the spring of 2002. The purpose of the survey was to identify and inventory the plant communities and individuals that would be subject to new disturbance in order to complete site-specific plans for salvage and transplanting and provide more detailed baseline characterization. During this survey, three sensitive plant species were observed within the ROW corridor: milkvetch (*Astragalus geyeri* var. *triquetrus*); yellow two-tone beard

Fig. 5. Salvaged yucca plants on the Kern River 2003 Expansion Project's Construction ROW with heeled-in DriWater™.

tongue, and Rosy two-tone beardtongue (*Penstemon bicolor* spp. *roseus*).

Native seed collection and live vegetation propagation

The Reclamation Plan provided for collection of mature seed from major shrub components identified along the ROW in the spring of 2002 using standard seed collection protocols, to best assure the use of native sources or local ecotypes. BLM specialists provided KRGT with guidance on the specific plant species from which to collect seeds prior to construction activities. Typically, seeds harvested from native shrubs within the ROW area were to be collected by a certified seed company, and when necessary, supplemented with locally available seed. Once collected, the seeds were to be cleaned, tested for germination (pure live seed), certified weed-free, and stored until required for reclamation. The propagated plants were to be maintained at an off ROW nursery until they attained a standard size of 6 inches, at which time the seedlings were to be transferred to the designated ROW planting area. Propagated seedlings were to be planted within the existing ROW in a natural pattern that blended with the adjacent plant community, with visual impact mitigation a major objective.

Because blackbush (*Coleogyne ramosissima*) made up a comparatively high proportion of the native plant communities in much of the Red Rock Canyon NCA, seed collection focused on this specie. During the collection efforts, however, attempts to collect native seed along the ROW proved to be generally unproductive. This was because the natural seed production in 2002 was very poor, presumably due to persistent drought conditions during the late winter and early spring of previous years growing periods. In addition, the time required for plant propagation would have precluded KRGT's goal of completing all primary restoration work in 2003, versus extending the restoration period and disturbance on the ROW over a period of years, other than monitoring and maintenance. With BLM concurrence, KRGT obtained seed from other commercial sources to make up the necessary inventory. As required by the BLM, seeds were obtained from plants in the same region of Nevada as opposed to other regions of the Mojave Desert. BLM worked cooperatively with KRGT to identify and make available local sources of plant materials.

Salvage of perennial shrubs and succulents

Prior to initial ROW clearing and grading, KRGT salvaged perennial shrubs and succulents that were previously identified as transplants. For the salvaged shrub species, blackbush and creosote bush (*Larrea tridentata*), plants were containerized in 12 to 16 gallon horticulture pots, treated for bacterial growth and maintained for a minimum of 4 months at an approved off ROW nursery. Succulents (cacti, yucca, Joshua trees, and agave specimens) that had a reasonable probability of transplant success were flagged for salvage/removal. Cholla cacti (*Opuntia* spp.) less than 3 feet tall, agave (*Agave* spp.) and other cacti (*Echinocactus* spp.; *Echinocereus* spp.; *Ferocatus* spp.) greater than 6 inches tall, and Joshua trees (*Yucca brevifolia*) less than 6 to 8 feet tall and with only a few branches were determined to have the most reasonable probability of success. Before removal from the existing ROW, the north orientation of each cactus was noted and recorded. Those salvaged were removed from the permitted pipeline corridor and planted or "heeled-in" adjacent to the working ROW. The soil around the plants was watered as necessary during the construction period. Once final grading of the ROW was accomplished, those salvaged plants were then distributed across the entire ROW width in a pattern that blended with the adjacent plant community.

Construction of the new Dry Lake Compressor Station resulted in long-term land use conversion, therefore all succulents removed from this area were relocated to a BLM-approved storage facility located at the Indian Springs and Tortoise Center nurseries. This material was later used for ROW restoration activities within the Red Rock Canyon NCA and Spring Mountain NRA.

Salvage of vertical mulch and rocks

When clearing, cutting and grubbing was required within the ROW limits or pipeline trench, the vegetation not salvaged was mechanically windrowed to an area outside the disturbance footprint and used as vertical mulch during ROW restoration. Large rocks and boulders were also removed to the side of the ROW to be used as vertical mulch to deter OHV use. When the cobbles or boulders were moved back into place during the final restoration phase, care was taken to realign that portion of the rock exhibiting desert varnish, a glossy sheen or coating on stones and gravel in arid regions, in an upward position so as to lessen the visual impact to the surrounding landscape.

KRGT used vertical mulch and rock placement to enhance the visual restoration, provide a barrier to OHV use, and control erosion. In areas exhibiting natural gravel, cobble, or boulder veneer (lag layer), the salvaged rocks not only blended with the surrounding area, but also provided additional erosion control. Typically, rock mulch slows wind velocities and absorbs rainfall impact, reducing the wind and water erosion potential. Rock mulch also provides microenvironments that may allow for the natural collection of plant seeds and moisture on the leeward sides of the rock face.

Topsoil segregation

Topsoil within the Red Rock NCA was removed at a typical depth of 4 to 6 inches over the trench and spoil storage zones, as well as those areas that involved cut and fill (side-slopes). To limit mixing with the subsoil horizons, KRGT stockpiled the topsoil separately from all excavated subsoils. When adverse weather conditions prevailed, i.e. high winds, the stockpiled topsoil was treated with a vegetable-base tackifier or water to a 2-inch wetting depth.

Soil treatment and topsoil replacement

Once the pipeline was assembled and placed in the trench, the excavated subsoil material was used as backfill over the pipe. Compacted soils, as determined by the environmental inspector, were then scarified to a depth of 6 inches utilizing heavy-duty disks, plows, or similar equipment. Sandy soils were not scarified.

Following scarification, the segregated topsoil was then spread evenly over the bladed area from which it was collected and left in a roughened condition. The use of a rough surface layer was intended to allow for the collection of wind blown seed, water accumulation and micro-relief against direct sunlight and desiccating winds.

Surface shaping

All graded or excavated areas on the construction ROW and ATWS were re-contoured to blend with the surrounding topography. The emphasis during re-contouring was to restore the existing drainage patterns and contours to the original conditions to the extent practicable.

Rock and vegetative mulch

Surface rocks and shrubs that were cleared from the ROW during construction were re-spread over the contoured topsoil surface to create microenvironments in which seeds and moisture could collect. Non-salvaged succulents were also laid down across the ROW as vertical mulch. During the final restoration phase, care was taken to realign that portion of the rock exhibiting desert varnish in an upward position so as to lessen the visual impact to the surrounding landscape. In addition, the original reclamation plan provided for the use of Permeon™ applications, a simulated patina used to restore the natural earth tones of a disturbed site, to help restore the appearance of desert varnish on the visually sensitive slope near the site known as Wilson Tank and other exposed rock faces found in this area. However, the BLM Natural Resource Specialist inspected the ROW after recontouring, replacement of rock outcrops and planting in the spring of 2003, and concluded that the initial visual restoration was adequate without the use of a Permeon™ application.

Imprinting

In non-rocky areas, an imprinting device was used to create small depressions or microenvironments that provide some shading or micro-relief against direct sunlight, concentrate moisture, and allow for the collection and retention of windblown seeds.

Water bars (slope breakers)

Water bars or slope breakers were installed across steep parts of the ROW to control surface water erosion. In general, water bars are a 1-foot high berm and uphill-side ditch that is angled very gently downslope, approximately 5° off the horizontal. Typically, KRGT installed water bars at a spacing relative to the percent slope encountered. For example, water bars were spaced every 300 feet on slopes of 1–5 percent; 200-foot spacing on slopes of 5–15 percent; and 100-foot spacing on slopes of 15–25 percent.

Direct seeding with native species

Seeding mixtures and rates

KRGT developed a native seed mixture for reclamation that is compatible with the vegetation types found within the Spring Mountain NRA and Red Rock Canyon NCA. The seed mixture and rates, identified within the original Reclamation Plan as NV-2, were formulated based on recommendations from the BLM Las Vegas Field Office and are listed in Table 1 below. The seeds were purchased from commercial seed vendors with the requirement that seeds collected must be from local ecotypes similar to the southern Nevada or Mojave Desert region. The commercial seed was tested for germination and purity and certified prior to reclamation use to ensure compliance with all state and federal requirements.

Table 1. Seed mixture utilized for Red Rock Canyon NCA and Spring Mountain NRA

Common name and species	Seed application rate (pounds/acre/PLS)[a]
Grasses	
Indian ricegrass (*Oryzopsis hymenoides*)	3.0
Desert needlegrass (*Stipa* (*Acnatherum*) *speciosum*)	0.5
Sand dropseed (*Sporobolus cryptandrus*)	1.0
Shrubs	
Four-wing saltbush (*Atriplex canescens*)	2.0
Blackbrush (*Coleogyne ramosissima, local variety*)	5.0
TOTAL	**11.5**

[a]Seeding rate is listed as pounds per acre of pure live seed (PLS). Seeding rate is doubled if broadcast or hydroseeded; except for Black brush or other species that cannot be drilled due to seed size or amount of inert material; in which case the broadcast rate is as specified above. Alternative species or seeding rates may be applied as approved by BLM, Las Vegas Office.

Seeding methods

The main purpose of the seeding methods followed was to place the seed in direct contact with the soil at an average depth of 0.5 inch, but not to exceed a depth of 1 inch; to cover the seed with soil; and to compress the soil around the seed in order to eliminate air pockets. Some methods of seeding are more effective at seed placement than others, and the terrain has an impact on the type of seeding method that is practicable. As such, KRGT chose the exact method of seeding during construction based on site-specific conditions.

Depending on the encountered slopes of the ROW, KRGT used broadcast seeding, drill seeding, and broadcast or drill seeding with an imprinter device to distribute seeds across the ROW. The broadcast method was accomplished utilizing a hand-operated, cyclone-type seeder, a mechanical broadcaster or a specially designed blower depending on the topography and/or soil surface conditions. This method distributes seed upon the soil surface without mulch with the seeds then incorporated into the soil via raking, chain drag, harrow, or imprinting. Although the direct drill method was the primary method for seed placement, it was limited in use to level or moderate slopes and within areas of limited rockiness.

Pelletized seeding

In consultation with the BLM Las Vegas Field Office, KRGT conducted an experimental pelletized seeding within the Red Rock Canyon NCA, as opposed to more widespread use since a literature review and consultations with other restoration experts concluded the use of pelletized seed was more experimental versus a proven technique used to increase the success of direct seeding. The plot runs nearly 4,000-feet in length along the entire ROW near Wilson Tank. Pelletizing involved the coating of the native seed (NV-2 mix) with macrobiotic components laboratory-grown especially for Mojave Desert habitats and selected to improve seed germination. The pelletized seed application mixture had at least 250 pounds of coating per at least 12 pounds of site-specific seeds. KRGT found that the use of pelletized seed cost about $950 per acre compared to standard drill or broadcast seeding with imprinting at an average of $600 per acre.

Seeding from sensitive plants

As mentioned earlier, 3 sensitive plants were identified within the survey corridor during the 2001 field season. In order to minimize or eliminate the disturbance to these plants, additional reclamation techniques were used, which included minimization of ROW construction activities within the identified plant population areas; protection of the plant habitat zones adjacent to and outside of the construction zones with flagging or fencing; salvage and replacement of topsoil; and the collection of seed from each of the designated sensitive species within the ROW disturbance vicinity.

The collected seed was incorporated into the seed mix within those areas previously identified as supporting these plants. Following consultation between KRGT and the United States Fish and Wildlife Service (FWS) concerning the potential hybridization between the native beardtongue (*Penstemon bicolor*) and an introduced beardtongue species (*Penstemon palmeri*), no seed collection nor propagation procedures were undertaken within areas where hybridization may have occurred.

Table 2. Numbers of transplants in the Red Rock Canyon NCA and Spring Mountain NRA

Common name and species	Number of transplants
Joshua Tree (*Yucca brevifolia*)	66
Yucca (*Yucca sp.*)	162
Cholla (*Opuntia sp.*)	16
Hedgehog cactus (*Echinocereus sp.*)	12
Pincushion (*Chaenactis sp.*)	10
Blackbush (*Coleogyne ramosissima*)	273
Waxberry (*Symphoricarpos sp.*)	22
Winterfat (*Krascheninnikovia lanata*)	9
Ephedra (*Ephedra sp.*)	58
Mendora (*Mendora sp.*)	44
Bitterbrush (*Purshia tridentata*)	151

Transplanting of perennial shrubs and succulents

Upon completion of final grading and topsoil replacement, the salvaged and propagated perennial shrubs and succulents (yucca, Joshua trees, agave, and cacti plants) were transplanted within the designated ROW areas (see Table 2). The succulent transplants were distributed across the entire ROW width in a pattern that blended with the adjacent plant community. All of the transplanted cacti were replanted based on their original north orientation (+/−15°). KRGT also worked with the BLM to implement site specific planting locations and patterns, and further emphasized placing the transplants in areas such as road crossings in order to provide for additional visual screening and OHV control. This also offered the advantage of the sites being accessible for watering once other sections of the ROW were re-contoured (including water bars), seeded and imprinted, and closed to vehicle access.

The specimens were typically transplanted in a vertical shaft approximately 18 inches deep. All transplants and propagated specimens were initially watered, with subsequent watering 1–2 weeks following planting as the restoration work was being completed and where the ROW was still accessible to water trucks and other vehicles and equipment. To prevent damage to the restored areas, KRGT has not accessed the ROW for additional watering since the final restoration was completed. When requested by the BLM, KRGT supplemented the watering efforts with DriWater™, a new alternative watering method that is made of time-released, non-toxic, biodegradable gel packs of water bound in a cellulose-alum matrix. Additional supplemental watering was also performed where plantings were concentrated at road crossings that remained accessible to equipment after the ROW was re-contoured and restored.

At the direction of the BLM Las Vegas Field Office and in an effort to enhance restoration efforts, KRGT transplanted additional succulent plant stock material, which was available at BLM's Indian Springs and Tortoise Center nurseries. In addition, some succulents and woody plants salvaged from the Dry Lake Compressor Station Site were also utilized.

Off-Highway Vehicle (OHV) controls

To minimize disturbance to the ROW and maximize success of the restoration techniques described above, KRGT installed signs along all restored areas in the Red Rock Canyon NCA and Spring Mountain NRA at regular intervals to deter OHV use. The restoration signs and t-posts were approved and provided by the BLM. These OHV signs were augmented by the placement of salvaged boulders back onto the ROW.

Application on new and adjacent existing ROW

To further eliminate residual impacts and demonstrate a net benefit for these special use areas, KRGT also applied revegetation treatments to the existing portion of its ROW that otherwise was not disturbed during construction. As previously mentioned, perennial shrubs were transplanted onto the entire ROW (existing ROW and new disturbed areas) and distributed in patterns to best represent or blend with adjacent plant communities. Additional direct seeding was also done on the existing ROW.

Post-construction monitoring

The KRGT post-construction Reclamation Monitoring Plan was developed in compliance with all reclamation plans developed for the Project and applicable federal and state permits or approvals. Field monitoring is being used to periodically evaluate the recovery status of the restored ROW, identify the need for additional remediation actions and to provide the permitting agencies with the necessary information to make a final determination concerning restoration success, and where applicable, to obtain releases from these agencies from any future ROW monitoring. Field protocols developed in the monitoring plan follow criteria established within the KRGT Reclamation Plan, the *Draft Restoration Success Standards and Monitoring Plan* (BLM November 2001) developed by the BLM Las Vegas Field Office and other existing guides, manuals and handbooks as published by federal and state agencies, experiment stations and universities. The monitoring plan also addresses compliance and reporting requirements for the FERC.

To ensure the success of the restoration methods, KRGT agreed to a 6-year monitoring program in the Red Rock Canyon NCA and Spring Mountain NRA. The purpose of post-construction monitoring is to determine whether areas that have been restored are progressing toward the long-term goals as specified in the reclamation plans. Restoration will be considered successful within these areas when native perennial vegetation (mainly dominant shrubs) equals or exceeds 80% of the cover, density and richness associated with the undisturbed reference area (control).

Two monitoring transects were placed at each of the selected monitoring stations, including 1 transect

Table 3. Seeding success in the Red Rock Canyon NCA and Spring Mountain NRA

Milepost	Location	Monitoring station	Restoration method	% Total cover[a]		Percent cover difference[b]
				ROW	Control	
547.1	Within NCA	NV-4	decompact, drill, imprint NV-1	48	60	80
558.0	Within NRA	NV-3	decompact, roughen, broadcast, imprint NV-2	28	80	35
558.5	0.2 mi S of NRA	NV-2	decompact, roughen, broadcast pelletized mix	8	48	17

[a]Total cover includes canopy and basal.

[b]Cover difference is basis for meeting success standards.

on the Project ROW and 1 transect in an undisturbed control area adjacent to the pipeline corridor, set an equal distance from a benchmark located at the ROW/control edge. The ROW and control monitoring transects were placed in such a manner so as to eliminate any physiographic discrepancies between them. Each of the permitting BLM field offices were provided a copy of the monitoring plan and monitoring station locales for their review and approval in advance of any field work activity. A total of 3 permanent monitoring sites have been established within the Red Rock Canyon NCA and Spring Mountain NRA.

Each of the monitoring stations in these special use areas has been permanently marked with 3/8-inch by 18-inch rebar, capped with a yellow *Permamark* plastic surveyor marker imprinted with *"Kern River"* and GPS-surveyed for ease of relocation in successive years. A line-transect/point-intercept method of data collection was followed in order to quantify ground cover that includes vegetative types, litter, rocks and biotic crusts. The associated data and plant lists will provide the basis for density and cover determinations. Qualitative observations were also included at each monitoring station and include evidence of soil disturbance; plant recruitment into the ROW; plant growth stages; invasive and noxious plants; animal use; and photographic documentation.

The monitoring stations located within the Red Rock Canyon NCA and Spring Mountain NRA are identified as NV-2, NV-3 and NV-4. The NV-2 location is within the pelletized seeding area near Wilson Tank. The NV-2 benchmark is located along the eastern ROW edge with the ROW transect line running 150-feet along the 214-degree azimuth and the control transect running 150-feet along the 110-degree azimuth. Location NV-3 benchmark is located nearly 0.5-mile north of NV-2 and is situated on the western edge of the ROW. Transects run 150-feet on a 35-degree azimuth for the ROW and a 295-degree azimuth for the control. NV-4 monitoring benchmark is situated north of the KRGT valve station, north of Highway 160. The NV-4 transects run 150-feet along a 300-degree and a 30-degree azimuth for the ROW and control respectively.

RESULTS CONCERNING REVEGETATION SUCCESS AFTER FIRST GROWING SEASON

Revegetation monitoring of the Project within the Red Rock Canyon NCA and Spring Mountain NRA was conducted on April 1 and 5, 2004. Reclamation work within these areas was completed by May of 2003. As such, these areas are considered to be entering their first full growing season.

When monitoring restoration in these areas, KRGT found that drill seeding with an imprinter was the most effective seeding methodology, as shown in Table 3. At monitoring location TR-NV-4, the ROW had a commonly abundant plant base developing, with fourwing saltbush (*Atriplex canescens*) dominating and bursage (*Ambrosia dumosa*) and brittlebush (*Encelia* sp.) subdominant. Total cover for the ROW and control transects was found to be 48% and 60% respectively. At monitoring station NV-3, where broadcast and imprinting was used, the area was developing a commonly abundant plant base dominated by saltbush. The total cover for the ROW was 28% and 80% for the control.

In contrast to the successful drill seeding, within the pelletized seeding area, NV-2, there was minimal vegetative growth during the first year field monitoring effort. Total cover was found to be 8% for the ROW and 48% for the control area. The ROW had little plant abundance and contained a dominance of red brome (*Bromus rubens*); filaree (*Erodium cicutarium*); and Russian thistle (*Salsola iberica*), with the soil surface being gravelly in nature.

The difference in total cover between the ROW and control monitoring locations at NV-2, -3 and -4 were 17%, 35% and 80% respectively. When compared to the success standard of 80% for this area, only monitoring location NV-4 has met this standard in the first full growing season. However, it is recognized that restoration is a continual process in desert environs, extending over a number of growing seasons, and the 80% criterion was established as the goal for success by the sixth growing season. It is also generally recognized that delayed germination the following year is a factor, along with colonization from adjacent seed sources.

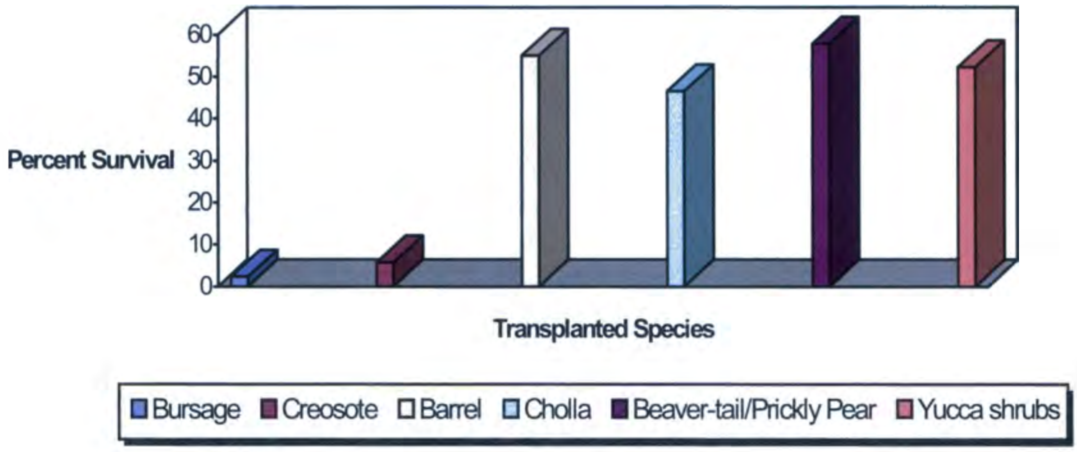

Fig. 6. Apparent vegetative survival one year post transplanting.

Transplanted vegetation within Red Rock Canyon NCA was qualitatively evaluated in 2004 at a BLM trail crossing of the ROW near Wilson Tank. Within this area, nearly 825 different plant species were placed during restoration activities. Figure 6 presents a graph indicating apparent vegetative survival, as a percent, after the first transplant year within the Mojave Desert along the ROW corridor (McMahon et al., 2004). As shown, it is apparent that the cacti group, including barrel, Cholla, and Opuntia species, and yucca shrubs had a higher survival rate than the creosote and bursage deciduous shrub species. However, it is noted that while some survival percentages appear low, some transplanted species, such as blackbush and yucca, can exhibit apparent mortality or die-back, and then recover the following growing season under periods of more favorable moisture conditions (Plath and Heffernan, 2003). Although no definitive count of transplanted species was conducted at the Red Rock Canyon NCA site during the 2004 monitoring period, qualitative observations indicate similar results within this area. Success of transplants will be further evaluated in subsequent growing seasons.

CONCLUSIONS

KRGT designed and implemented more intensive restoration treatments on the Project ROW through Red Rock Canyon NCA and Spring Mountain NRA to demonstrate that the Project created a net benefit. Measures in these special use areas included: field consultation with BLM and other stakeholders; baseline vegetation surveys; salvage of both succulent and non-succulent shrubs; topsoil segregation; placement of vegetative and rock mulch to enhance visual restoration and deter OHV use; direct seeding with native species; and the trial use of specialized/pelletized seed. Based on the first year of restoration monitoring, ROW revegetation is generally proceeding toward the 80% success criterion as specified for the sixth growing season. The ROW was found to be stable and free of areas of accelerated wind or water erosion which in themselves contribute greatly to restoration success. Based on the initial establishment of seeded species the first full growing season after construction, the data to date indicates that drill seeding with an imprinter device is the most effective method for this area. In addition, KRGT found that pelletized seeding was not cost effective based on observations on initial establishment of the desired species the first full growing season.

The transplanting of salvaged succulents was most successful for the cacti group. Although the larger transplanted species may eventually take root and overcome the stress associated with salvage and transplanting, dieback and a longer recovery period may occur within the transplanting area. While conclusions based on the first growing season must be considered preliminary, the 6-year monitoring program is expected to yield much useful information that can be applied realistically to future projects.

ACKNOWLEDGEMENTS

Special acknowledgements are extended to KRGT and its construction contractors for the implementation of the Restoration Plan and their commitment and support of successful revegetation of the ROW through the Red Rock Canyon NCA and Spring Mountains NRA. The authors particularly recognize the expertise and workmanship of Granite Seed and Bitterroot Restoration, who acquired the seed and prepared the mixes of the seed and conducted the plant salvage and planting respectively. The authors also express their appreciation to all involved from the BLM Las Vegas Field Office who provided and worked with KRGT from inception of the original plans through construction and restoration.

REFERENCES

Bureau of Land Management, Las Vegas Field Office and Native Resources. September 2001. Restoration Plan (Draft) for Energy Projects in the Las Vegas Field Office. Las Vegas, Nevada.

BLM, Las Vegas Field Office. November 2001. Restoration Success Standards and Monitoring Plan (Draft). Las Vegas, Nevada.

BLM, Las Vegas Field Office. 2004. Red Rock Canyon National Conservation Area Website. Available online at http://www.redrockcanyon.blm.gov/. Follow links to Activities, Planning Your Visit, and Resources.

Dames & Moore, Inc. 1990. Kern River Pipeline Reclamation Plan, Nevada and California Portions, Kern River Gas Transmission Company.

Federal Energy Regulatory Commission. 2002. Final Environmental Impact Statement/Environmental Impact Report for the Kern River 2003 Expansion Project.

Ecology and Environment, Inc. 2002. Kern River 2003 Expansion Project, Reclamation Plan, Nevada and California Portions, KRGT Gas Transmission Company.

McMahon, Sara, Brent Arnold, Tim Powell, George Welsh, and Paul Smith. 2004. Desert Restoration on Pipeline Rights-of-Way. Published in the proceedings for the 8th International Rights-of-Way Symposium, School of Environmental Science and Forestry, Syracuse State University, Syracuse, New York.

Plath, Steven and Lisa Heffernan. Bitterroot Restoration. March 29, 2003. Personal Communications with G. Welsh, Ecology and Environment, Inc. Castle Mountain Mine, Search Light, California.

United States Forest Service, Humboldt-Toiyabe National Forest. 2004. Available online at http://www.fs.fed.us/r4/htnf/index.shtml. Follow links to Spring Mountain NRA and Maps and Brochures.

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Desert Restoration on Pipeline Rights-of-Way

Sara McMahon, Brent Arnold, Tim Powell, George Welsh, and Paul Smith

Prior to construction of its 2003 Expansion Project through the Mojave Desert in southern Utah, Nevada and California, Kern River Gas Transmission Company (KRGT) researched existing desert restoration methods and their efficacy by reviewing scientific literature and consulted with restoration specialists experienced in the region. Literature indicates that natural perennial revegetation of pipeline corridors in the Mojave Desert can take from 30 to 100 years, with continued third-party disturbance, such as use of the right-of-way (ROW) for access, as major factors in limiting the restoration process. Recent studies indicate more intense restoration techniques could speed the rate of desert restoration. However, KRGT's research and consultation also showed that restoring desert environs is more expensive, with no consensus that direct seeding is generally successful. Restoration efforts, generally, were found to cost $5,000 to $10,000 per acre or higher. KRGT worked with the Federal Energy Regulatory Commission (FERC), Bureau of Land Management (BLM) and other cooperating agencies and landowners to implement more intense desert restoration methods, including topsoil segregation, surface preparation, plant salvage, use of other transplants, direct seeding and off-highway vehicle (OHV) control on its 320-mile looping in the Mojave Desert. Kern River also worked to establish monitoring success criteria over a six-year period. The revegetation effort involved about 100,000 plants and seeding along approximately 4,300 acres of ROW in the late winter and spring of 2003. Due to favorable moisture conditions in the spring of 2003, germination and initial establishment occurred in many locations. Further assessment of the preliminary success of plant salvage and seeding was made in the spring and summer of 2004 and presented.

Keywords: Bureau of Land Management (BLM), desert restoration, fast-tract, Federal Energy Regulatory Commission (FERC), Kern River Gas Transmission Company (KRGT), off-highway vehicle (OHV), pelletized seed, revegetation, right-of-way (ROW), transplanting, nurseries, propagation, monitoring, success criteria

INTRODUCTION

The Kern River 2003 Expansion Project (the Project) was the first major natural gas project recently approved and constructed under a more fast-track Federal Energy Regulatory Commission (FERC) 7(c) certification and permitting process. In general, this process is similar in concept to the voluntary FERC pre-filing process currently in use on a number of projects, for which formal guidance and requirements have since been developed by the FERC and cooperating agencies. In order to facilitate more expedited review and approval of the Project, Williams Gas Pipeline (WGP) and Kern River Gas Transmission Company (KRGT) entered into pre-filing consultation with federal and state agencies on issues including restoration of the right-of-way (ROW) as one of the major project-wide issues.

To minimize visual and biological impacts, WGP and KRGT designed and implemented an extensive set of proven and innovative restoration methods to restore the ROW. Prior to construction through the Mojave Desert in southern Utah, Nevada and California, KRGT researched existing desert restoration methods and their efficacy by reviewing scientific literature and consulting with Mojave Desert restoration specialists. This paper provides an overview of the literature review and consultations, including those proven restoration methods based on case studies, as well as information on the restoration methods used on the Project and the success to date.

Environmental Concerns in Rights-of-Way Management: Eighth International Symposium
J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (editors)

BACKGROUND

Kern River 2003 Expansion Project

KRGT completed the expansion of its interstate natural gas pipeline system in May of 2003. The expansion, known as the Kern River 2003 Expansion Project (the Project), extends from southwestern Wyoming to southern California. It involved the construction of approximately 720 miles of 36 and 42-inch diameter pipeline loops along the existing mainline, including 69.3 miles in Wyoming; 341.4 miles in Utah; 120.6 miles in Nevada; 104.0 miles on the Mainline in California; 82.2 miles on the Mojave Common System (California); and an 0.8-mile, 12-inch diameter pipeline lateral extension in Uinta County, Wyoming. The Project also included construction of 3 new compressor stations in Wyoming, Utah and Nevada; modifications to 6 existing compressor stations in all 4 states; modifications to meter stations in Wyoming and California; 24 pig launcher/receiver facilities and 55 mainline valves (Fig. 1).

Except where required by topography, land use, presence of other utilities, or other constraints the pipeline loops were laid at a typical 25-foot offset from the existing pipeline utilizing a 75- to 90-foot construction ROW with additional temporary work space (ATWS) where required for road and railway crossings, streams and washes, side hills, and other limiting features. Launcher/receiver facilities and mainline valves were constructed within the fence lines of or adjacent to other aboveground facilities to the extent feasible to minimize impacts. Construction activity was restricted to the approved corridor environmentally inventoried and surveyed during 2001 and 2002. Where additional space was required for ATWS or for modifications to existing access roads, surveys were conducted immediately prior to construction in the fall of 2002 by biological monitors and accepted as variances to the construction permit by regulatory agencies.

OVERVIEW OF RESTORATION METHODS

Literature review

Based on recommendations made by the BLM's Barstow Field Office, KRGT researched existing desert restoration methods and their efficacy and integrated these findings into Project Restoration Plans. KRGT consulted restoration specialists familiar with reclamation in the Mojave Desert, including members of the Desert Managers Group (DMG), Edwards Air Force Base (EAFB), and the National Park Service (NPS). KRGT also conducted a comprehensive review of existing scientific literature.

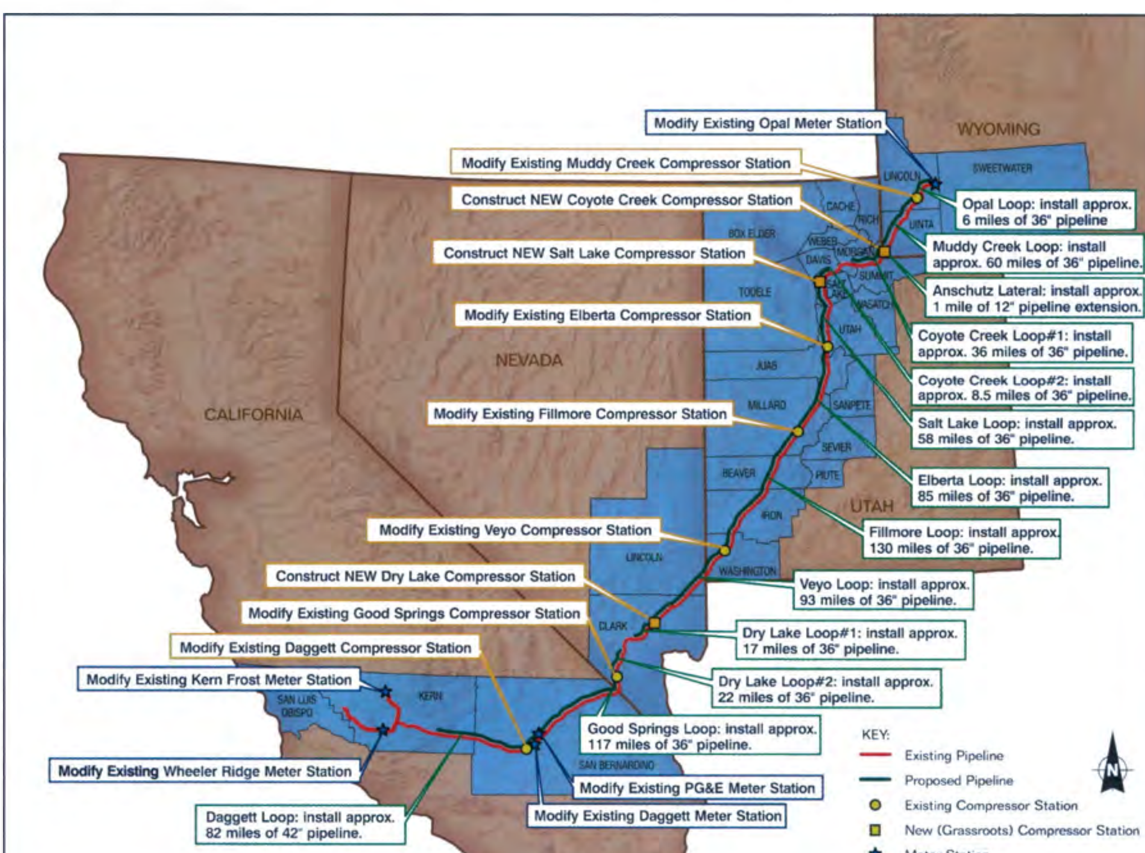

Fig. 1. Location of Kern River 2003 expansion project facilities.

While it has been found that natural perennial revegetation of pipeline corridors in Nevada and California can take from 30 to 100 years (Bainbridge et al., 1993), ongoing maintenance or third-party disturbances, such as off-highway vehicle (OHV) use, mountain biking, hiking, and other recreational activities, and access roads are considered the foremost cause of ongoing disturbance along older, existing pipeline corridors (Artz, 1989). In a review of existing scientific research pertaining to arid lands restoration, particularly in the Mojave Desert, the following potentially successful desert restoration techniques were identified:

- Topsoil segregation and salvage of microbiota;
- Soil Treatment (ripping, scarification, spading);
- Surface shaping (pitting, imprinting);
- Seeding;
- Transplants;
- Seedlings;
- Mulching;
- Reducing visual contrast (mulching, feathering);
- Gully control; and
- Watering and irrigation.

Restoration techniques

Restoration of a disturbed ROW within a desert ecosystem requires the careful removal and segregation of the limited topsoil layer prior to trench excavation were mixing with the subsoil layers can occur. Topsoil contains native seeds, organic matter, nutrients, symbiotic bacteria, and fungi important to desert plant growth.

Once backfilling of the trench is complete, the reclaimed ROW should include additional soil treatment options such as scarification, deep ripping, spading, rototilling, and surface shaping to alleviate the compacted soils. Use of these techniques is critical in desert regions as it allows for an increase in water infiltration and soil aeration, thereby facilitating increased moisture retention and allowing for greater root development, which in turn may increase plant survival and growth rates. Where deep ripping is not necessary or feasible (due to level of compaction, terrain contours, equipment or other limitations), power augers, shovels, or garden forks can be used to break-up compacted soils and facilitate plant growth (Bainbridge et al., 1995a).

By replacing the topsoil within a few months after the initial disturbance and after soil treatment, the area has a greater chance of returning to pre-disturbance conditions. Final surface shaping techniques (pitting and imprinting) can be used in conjunction with ripping, scarifying, or spading to reduce soil compaction, and is also recommended as a method to concentrate runoff and increase soil moisture. Soil pitting is the creation of depressions in the ground, which serve to improve water retention and infiltration and reduce evaporation. Ideal pitting size is 2 feet by 2 feet by 1 foot deep (Bainbridge, 2002b). Mechanical pitting was used successfully at Fort Irwin, Lake Mead, Castle Mine Mountain, and the Joshua Tree National Park (Rodgers, 2002; Bainbridge, 2002b). Land imprinting is another method used to concentrate available rainfall. Imprinting uses modified rollers to convert smooth-sealed soil surfaces into rough-open surfaces with micro-rainfall catchments that increase water infiltration, water retention, water runoff/erosion control, and soil fertility. Imprinting was identified as the most successful practice with the potential for re-vegetating large or steep disturbed areas (Bauder and Larigauderie, 1991; Dixon, 1988; 1994) and studies conducted on Arizona and Utah dry lands showed a dramatic increase in plant coverage using imprinting when compared to untreated, drill-seeded or hand-seeded land (Dixon, 1990). To improve the restorative value of imprinting, seeds should be spread at the same time as imprinting (Bauder and Larigauderie, 1991).

Successful reseeding of disturbed pipeline corridors within desert environs is directly related to precipitation amounts, and is widely viewed by many researchers and restoration specialists as a waste of desert seeds, which are difficult and costly to obtain, (Rodgers, 2002) as favorable growing conditions for seed germination and seedling establishment are infrequent and unpredictable (Bainbridge et al., 1995b). Despite those sentiments, the California BLM Barstow Field Office recommends direct seeding for reclamation projects in the desert. They developed a set of standard seeding guidelines to improve restoration success that include recommendation for seed mixtures which contain one appropriate native species from each of the shrub, grass, and forb groups (BLM, 2002). Example species include four-wing saltbush (*Atriplex canescens*), creosote brush (*Larrea tridentata*), Indian ricegrass (*Achnatherum hymenoides*), and lacy-leaved phacelia (*Phacelia tanacetifolia*). Additionally, the BLM Las Vegas Field Office is experimenting with the application of seeds mixed with a bitter-tasting coating (pelletized seed) that would prevent animals from eating the seeds, and extending the period of time in which the seeds remain dormant in advance of adequate rainfall. When adequate precipitation is then received the pelletized coating would then dissolve and allow the seed to germinate.

Salvage and transplanting of live plants for desert restoration may significantly increase the rate of plant establishment, provide plants of up to 100 years in age, and provide necessary micro flora, which may be lost during topsoil storage (Franson and Bainbridge, 1993). Transplanted Joshua trees (*Yucca brevifolia*) and succulents can also serve as a valuable ecological–architectural feature (Bainbridge, 2002b). Requirements of plants chosen for transplantation are based on their size and health, and should be removed from the disturbance area either by hand digging or with a backhoe or spade prior to topsoil segregation or initial grading. After surface shaping and reseeding, the transplants are typically replaced to their original location and orientation to the extent feasible. Because transplants have a greater chance of survival if they are replanted soon after removal, shipment of transplants to a nursery for storage is not recommended (Bainbridge, 2002b) and should be placed in a secure nursery as close to their original location as is practicable. Joshua trees, other yucca species, and cacti are regularly salvaged and transplanted with high rates of revegetation success (Rodgers, 2002; Bainbridge, 2002b) at several restoration sites, including the Mojave Desert Gold Mine, Joshua Tree National Park, along the Mojave Pipeline, and the Morongo Basin Pipeline.

Use of nursery-grown shrub seedlings and other desert plants is an important aspect of desert restoration (Fidelibus and Bainbridge, 1993; Rodgers, 2002; Bainbridge, 2002b). Unlike yucca and cacti species, shrubs often have higher success rates when they are planted from nursery-grown stock rather than when transplanted from a disturbed area (Bainbridge, 2002b). Researchers have found that plant recovery usually requires container-planting activities in addition to other techniques (Lovich and Bainbridge, 1999).

Mulch placement as a restoration technique for disturbed ROWs can provide wind protection, improve the plant microclimate, reduce erosion and evaporation, and increase water retention and infiltration. While mulch can reduce erosion, it is often unnecessary in the desert region (Bainbridge et al., 1995a). Some research indicates that hydro-mulch, a soil tackifier or crimped straw has a poor success record in dry climates (Bainbridge, 1994). In the absence of a plentiful water supply, mulch can absorb water from surrounding plants, and may hinder seed germination due to its size and weight (SERG, 2000b). Other research has found that application of a tackifier over the mulch can prevent wind from blowing the mulch from disturbed areas thereby increasing the value of the mulch in desert restoration (Mull, 2002). Vertical mulching is an alternative method involving the placement of straw, sticks, brush or dead plant material upright in the soil. Vertical mulch provides many benefits, including slowed water movement, open channels for water penetration, micro-sites for growth, wind breaks to trap seed and dust, shade and cover for seedlings and animals, and protection against traffic disturbance (Bainbridge, 1994; Rodgers, 2002). Experiments have shown that vertical mulch can increase soil moisture storage by greater than 20% (Fairbourn, 1975), which may be critical in the desert. Shredded brush is also beneficial to discourage off-highway vehicle traffic, which is highly detrimental to restoration success (Bainbridge, 2002b). However, the use of vertical mulch can be expensive on large-scale projects. At the Joshua Tree National Park, vertical mulching has been used primarily in visually sensitive areas to reduce the visual contrast between disturbed and undisturbed areas (Rodgers, 2002).

One of the most difficult aspects of desert restoration is reducing the visual contrast between disturbed and undisturbed areas. This contrast may be due to differences in soil color (Rodgers, 2002) or to reduced rates of growth on the disturbed area. In addition to general re-contouring, methods to minimize visual contrast include vertical mulching, as described above, and feathering. Feathering refers to the placement of rocks, seedlings and salvaged plants in more natural looking clumps or patterns along the edges of the disturbed area to reduce the linear contrast created by uniform clearing or working limits. Where restoration funds are limited, efforts should be concentrated at visually sensitive areas as well as at access points and critical habitats (Bainbridge, 2002b).

To reduce water erosion potential, restoration specialists recommend construction of check dams and water bars (Bainbridge et al., 1995a) on sloping landscapes. Use of permanent erosion control measures may also aid in the establishment of desert vegetation by limiting the effects of high-intensity, low-duration rain events that can produce rapid water runoff from un-vegetated areas and steep slopes resulting in the development of gullies. Additional research indicates that such gullies can increase several feet in depth after a single storm (Bainbridge et al., 1995a).

The capturing of water through surface-shaping techniques such as pitting and imprinting help to concentrate rainfall for use by seeds and new plants, without increasing erosion potential. In addition, regular manual watering can increase plant survival. Seedlings and transplants should be watered immediately after being planted. If long-term irrigation is feasible, hand watering, deep pipe irrigation, sprinkling, drip systems, and buried clay-pot irrigation may also be considered. Irrigation and hand watering of plants are expensive means to aid survival in desert revegetation projects, and they are of limited practicality on long, restored ROWs where regular equipment access is not planned or desirable. The use of DriWater®, a new alternative watering method that is made of time-released, non-toxic, biodegradable gel packs of water bound in a cellulose-alum matrix is quickly gaining popularity in desert restoration. Naturally occurring soil microbes slowly degrade the water bound matrix, and the plant absorbs the released water as needed over time.

CASE STUDIES IN SUCCESSFUL RESTORATION

Recent desert restoration projects indicate that more intensive restoration methods could speed the rate of desert recovery after disturbance. For example, Viceroy Gold operates the Castle Mountain Mine in the East Mojave National Scenic Area of Baker, California.

Reclamation methods employed at this location include salvaging live plants, stockpiling and replacing topsoil, deep ripping (with 6-foot teeth), pitting, and planting of seedlings and salvaged succulents (Franson and Bainbridge, 1993; Bainbridge, 2002b). Of all the salvaged plants, the smaller Joshua trees, yucca, and cacti were found to have the best transplantation survival rates (Bainbridge, 2002b).

The Soil Ecology and Restoration Group (SERG) began restoring an area previously disturbed by off-highway vehicles within the Red Rock Canyon State Park in the southwestern Mojave Desert (SERG, 2000a). Seedlings were planted in the South Flat area, watered regularly, and monitored for one year. The overall survival rate for the seedlings planted in 2000 was 56%, slightly higher than most previous restoration projects conducted at this site. Saltbush had the highest survival rate at 83%.

A comprehensive restoration plan was developed for the National Training Center at Fort Irwin, a military base in the Mojave Desert 30 miles north of Barstow, California, in an effort to alleviate damage caused by military training activities. The listed techniques below were followed (Mason, 2001):

- Preservation of existing plants;
- Seed collection;
- Ripping of soil to depths of 30 cm to 3 feet;
- Pitting on slopes;
- Manufacturing micro-catchments;
- Direct seeding;
- Planting of shrubs and trees in vegetative islands;
- Installation of irrigation systems using deep pipes and drip irrigation; and
- Construction of berms to protect sites from further vehicular damage and wind.

Subsequent monitoring of the reclaimed desert indicates direct seeding was proven to be ineffective under dry conditions. Additionally, pitting and micro-catchments were found effective in aiding plant survival through their ability to concentrate rainfall. The use of DriWater® was also tested during the restoration effort and showed that plants irrigated with DriWater® had higher survival rates than those without (SERG, 1998).

Follow-up restoration surveys at the Marine Corps Air Ground Combat Center at 29 Palms, California evaluated the success of several restoration techniques, which included ripping, imprinting, pitting, mulching, hand-seeding, transplanting seedlings, and use of DriWater® (SERG, 2000b). Direct seeding was found less effective than transplanting. While fertilizer and mulch treatments increased nitrate levels and organic matter, respectively, mulching was found to be ineffective, if not detrimental, in seeded areas and did not have a significant effect on plant survival. In addition, ripping combined with imprinting and direct seeding of a large disturbed area was found to be a practical restoration method.

The 71-mile Morongo Basin Pipeline was completed in October 1994 and began delivering water to the Yucca Valley area in January 1995. Restoration efforts included salvaging and transplanting Joshua trees and cacti, land imprinting, and seeding the entire temporarily disturbed ROW with native plant seeds (BLM, 1992). Based on consultation with the BLM Barstow office, the Morongo Basin Pipeline is an example of successful desert restoration. Additionally, the Mojave Natural Gas Pipeline Project ROW is an example of successful natural restoration of arid lands (Scofield, 2002; Mull, 2002). Restoration of this ROW was accomplished only by imprinting the disturbed area after final grading with no seed placement performed. Although there remains evidence of the ROW, *in-situ* desert plants are naturally re-vegetating the disturbed area.

KERN RIVER RESTORATION METHODS

The Project ROW traverses the Mojave Desert for approximately 320 miles, from the south side of Jackson Wash in southern Utah to the end of the Common Facilities in Kern County, California. The Mojave Desert landscape consists of discrete rugged mountains ranges dominated by an alluvial fan and playa basin physiography. The predominant vegetation types found along the Project corridor are creosote-bursage and blackbush scrub, with intermixing of Joshua tree woodlands and shrubland communities.

KRGT worked with the FERC, BLM, NRCS and other cooperating agencies and landowners to implement more intensive desert restoration methods, which included: topsoil segregation; surface preparation; plant salvage; direct seeding; and OHV controls on its 320-mile looping within the Mojave Desert. KRGT also worked to establish monitoring success criteria over a 6 year period. The overall restoration effort included the planting of approximately 100,000 transplants and seedlings at designated locations of the 4,300 acre ROW during the late winter of 2002 through the spring of 2003.

KRGT developed and implemented reclamation methods to include no impacts to off-ROW locations and minimization of new disturbances. KRGT salvaged succulents (cacti, yucca, Joshua trees, and agave specimens) from the ROW prior to initial clearing and grading activities. Succulents that had a reasonable probability of transplant success were flagged for salvage/removal with their north orientation being noted and recorded. Cholla cacti (*Opuntia* spp.) and yucca (*Yucca* spp.) shrubs less than 3 feet tall, other cacti (*Echinocactus* spp.; *Echinocereus* spp.; *Ferocatus* spp.) and agave (*Agave* spp.) greater than 6 inches tall, and Joshua trees (*Yucca brevifolia*) less than 6 to 8 feet tall and with only a few branches were determined to have the most reasonable probability of transplant success. When plant size or conditions were deemed unsuit-

Fig. 2. Photo of salvaged Yucca plants along the construction ROW with heeled-in DriWater®.

able for transplanting, these plants were windrowed along the edges of the temporary ROW and used as vertical mulch during final restoration. The salvaged plants were removed from the permitted pipeline corridor and planted (heeled-in) adjacent to the working ROW in 'nurseries'. The soil around the plants was watered as necessary during the construction period and when requested by the BLM, KRGT supplemented the watering efforts with DriWater® (Fig. 2).

Following the plant salvage operations, topsoil removal from the ROW commenced on BLM and USFS lands, and on privately owned lands as requested by the landowner. Topsoil was removed at a typical depth of 4 to 6 inches over the trench and spoils storage zones, as well as in those areas that involved cut and fill (side-slopes). To limit mixing with the subsoil horizons, KRGT stockpiled the topsoil separately from all excavated subsoils. When adverse weather conditions prevailed, such as high winds, the stockpiled topsoil was treated with a vegetable-base tackifier or water to a 2-inch wetting depth. Additionally, surface rocks and large vegetation were cleared from the construction zone and windrowed to the edge of the ROW for use as natural mulch during restoration activities.

Once the pipeline sections were assembled and lowered into the trench, the excavated subsoil material was used as backfill over the pipe. Compacted soils, as determined by the environmental inspector, were then scarified to a depth of at least 6 inches utilizing heavy-duty disks, plows, or similar equipment. Sandy soils did not require scarification since they proved not to be subject to compaction under dry conditions. Following scarification, the segregated topsoil was re-spread evenly over the work area from which it was collected and left in a roughened condition. The use of a rough surface layer was intended to allow for the collection of wind blown seed, water accumulation and micro-relief against direct sunlight and desiccating winds.

All work zones on the construction ROW and ATWS were re-contoured to blend with the surrounding topography. The emphasis during this phase of reclamation was to restore the existing drainage patterns and contours, to the extent practicable, to their original conditions. Surface rocks and non-salvaged shrubs that were cleared from the ROW during clearing operations were then spread over the re-contoured topsoil surface to create microenvironments in which seeds and moisture could collect. Non-salvaged succulents were also laid down across the ROW as vertical mulch. Where desert varnish, the glossy sheen or coating on stones and gravel in arid regions, was present these rocks were positioned facing up, to the extent possible, during reclamation activities to minimize the visual impact. To further alleviate visual impacts and deter OHV use, excess shrubs and rocks were placed at road crossings and other sensitive areas.

In non-rocky areas, an imprinting device, typified by a sheeps-foot roller, was used to create small depressions or microenvironments in an effort to provide some shading or micro-relief against direct sunlight, concentrate moisture, and allow for the collection and retention of windblown seeds.

Water bars were installed across the steeply sloping parts of the ROW to control surface erosion. In general, a water bar is a 1-foot berm and uphill-side ditch that is angled very gently down-slope, approximately 5°

off the horizontal. Typically, KRGT installed water bars at a spacing relative to the percent slope encountered. For example, water bars were spaced every 300 feet on slopes of 1–5 percent; 200-foot spacing on slopes of 5–15 percent; and 100-foot spacing on slopes of 15–25 percent. The purpose of a water bar is to slow and divert surface water from the ROW to vegetated stable areas in order to lessen the erosion potential along the pipeline corridor.

KRGT, in conjunction with the regulatory agencies, developed 6 seed mixtures for use during restoration of the ROW within the Mojave Desert. Of the 6 seed mixtures developed, 1 was specifically formulated for the Mojave Desert portions of southern Utah and eastern Nevada, 1 for the Red Rock Canyon National Conservation Area (NCA) and Spring Mountain National Recreation Area (NRA) in Nevada, and 4 were formulated for use in California. The formulated seed mixtures were then blended by commercial vendors utilizing seeds acquired from local sources within that portion of the Mojave Desert. The seed mixture was then tested for purity and certified weed free prior to use to ensure compliance with state and federal seed requirements. As an experimental restoration method, a portion of the restoration seed mixture was pelletized to test the efficacy and cost effectiveness of this method in desert restoration. Pelletizing of seed involves the incorporation of a nutrient rich and inert binding coat placed around the selected seed in an attempt to delay germination until favorable moisture conditions are encountered. For this project, the pelletized seeds were coated with macrobiotic components laboratory-grown especially for Mojave Desert habitats. The pelletized seed application mixture had at least 250 pounds of coating per at least 12 pounds of site-specific seeds. Two, 10-acre sections of the ROW were identified with 1 in California and the 1 in the Red Rock Canyon NCA and Spring Mountain NRA in Nevada. These sites are considered demonstration or trial areas in an effort to compare germination and establishment results against standard seeding methods where non-pelletized seed was used.

The primary purpose of the seeding methods chosen was to place the seed in direct contact with the soil at an average depth of 0.5 inch, but not to exceed a depth of 1 inch; to cover the seed with soil; and to compress the soil around the seed in order to eliminate air pockets. Although some methods of seed placement are more effective than others, KRGT chose the exact method of seeding, either direct drilling, broadcasting or imprinting, during construction activities based on site-specific conditions. Depending on the slopes encountered along the ROW, KRGT used broadcast seeding, broadcast seeding with an imprinter, or direct drill seeding to place seeds across the ROW. The broadcast method was accomplished utilizing a hand-operated, cyclone-type seeder, a mechanical broadcaster or a specially designed blower depending on the topography and/or soil surface conditions. This method distributes seed upon the soil surface without mulch with the seeds then incorporated into the soil via raking, a chain drag, harrow, or imprinting. Although the direct drill method was the method of choice for seed placement, it was limited in use to level or moderate slopes and within areas of limited rockiness (Fig. 3).

Upon completion of final grading and topsoil replacement, the salvaged and propagated perennial shrubs and succulents (yucca, Joshua trees, agave, and cacti plants) were transplanted within the designated ROW areas. The yucca (*Yucca* spp.), agave, and cacti transplants were distributed across the entire ROW width in a pattern that blends with the adjacent plant community. All of the cacti were transplanted based on their original north orientation (±15°). KRGT emphasized placing the transplants in areas such as road crossings in order to provide for additional visual screening and OHV control. The specimens were typically transplanted in a vertical shaft approximately 18 inches deep. All transplants and propagated specimens were initially watered, with subsequent watering 1–2 weeks following planting as the restoration work was being completed and where the ROW was still accessible to water trucks and other vehicles and

Fig. 3. Initial germination and seedling establishment on the ROW, Kern County, California.

Fig. 4. Photos of transplanting of succulents.

equipment. To prevent damage to the restored areas, KRGT has not accessed the ROW for additional watering since the final restoration was completed. When requested by the BLM, KRGT supplemented the watering efforts with DriWater™, a new alternative watering method that is made of time-released, non-toxic, biodegradable gel packs of water bound in a cellulose-alum matrix. Additional supplemental watering was also performed where plantings were concentrated at road crossings that remained accessible to equipment after the ROW was re-contoured and restored. A root hormone, Surperthrive™, was also added to the irrigation water given to Joshua trees in California (Figs. 4 and 5).

Fig. 5. Photo of planting woody riparian species at Meadow Valley Wash.

Kern River recognized that OHV use by other parties is a factor that affects the success of the erosion control and revegetation efforts. To deter OHV use of the ROW KRGT under took the following:

- Removed all temporary equipment bridges on the ROW;
- Removed temporary gates and replaced at fence lines;
- Installed erosion control structures, and most importantly;
- Installed OHV controls at the intersections of roads or trails as directed by BLM, including:
  - vertical mulch (such as large Joshua trees laid down over the ROW);
  - earthen or rock berms and breaches; and
- Where determined by BLM or other land management agencies, KRGT also installed educational or other signage with the intent of further controlling undesirable OHV usage.

In addition to the reclamation procedures and measures used through the Mojave Desert, KRGT implemented additional specific reclamation treatment procedures in sensitive areas. Because the desert tortoise is the most significant wildlife species occurring along the ROW through the Mojave Desert, Kern River implemented all of the reclamation practices formulated for Mojave Desert treatments within Desert Tortoise Critical Habitat Areas, and established higher success standards. In addition, KRGT coordinated with BLM, individual grazing allotment holders, and other private landowners for control or deferral of cattle grazing from the restored pipeline corridor to allow adequate time for the seeded areas to become established in these critical areas.

For the Red Rock Canyon NCA and Spring Mountain NRA in Clark County, Nevada, KRGT implemented additional measures, as detailed in the paper *Restoration on Pipeline Right-of-Way Through Red Rock Canyon National Conservation Area, Nevada* contained in these proceedings (McMahon et al., 2004). Additional succulent and shrub plantings were also installed as an enhancement measure at locations on the original ROW that were designated part of the Mojave National Preserve subsequent to construction of the original ROW, in San Bernardino County, California. KRGT also routed the Project loop outside the current boundaries of the Mojave National Preserve to a designated utility corridor.

COST OF RESTORATION

As the literature and case studies indicate, there is no consensus as to which restoration technique is best suited for desert restoration of disturbed ROW areas. However, these studies do point out that more aggressive reclamation methods can speed the rate of desert restoration significantly.

KRGT found that restoring the desert region along the Project ROW within the Mojave Desert, utilizing the methodology presented above, generally cost between $5,000 to $10,000 per acre or higher.

Monitoring and maintenance

The KRGT post-construction Reclamation Monitoring Plan was developed in compliance with all reclamation plans developed for the Project and applicable federal and state permits or approvals. Field monitoring is being used to periodically evaluate the recovery status of the restored ROW, identify the need for additional remediation actions and to provide the permitting agencies with the necessary information to make a final determination concerning restoration success, and where applicable, to obtain releases from these agencies from any future ROW monitoring. Field protocols developed in the monitoring plan follow criteria established within the KRGT Reclamation Plan, the *Draft Restoration Success Standards and Monitoring Plan* (BLM, 2001) developed by the BLM Las Vegas Field Office and other existing guides, manuals and handbooks as published by federal and state agencies, experiment stations and universities. The monitoring plan also addresses compliance and reporting requirements for the FERC.

To ensure the success of the restoration methods, KRGT agreed to a 6 year monitoring program in the Mojave Desert. The purpose of post-construction monitoring is to determine whether areas that have been restored are progressing toward the long-term goals as specified in the reclamation plans. Restoration will be considered successful when plant cover, density, and richness of native perennial vegetation (mainly dominant shrubs) of the ROW equals or exceeds 60% of the undisturbed reference area (control) and 70% of the reference area in Desert Tortoise Critical Habitat. The highest criterion of 80% was assigned to the Red Rock Canyon NCA and Spring Mountain NRA in Nevada.

Two monitoring transects were placed at each of the selected monitoring stations, including 1 station on the Project ROW and 1 station in an undisturbed control area adjacent to the pipeline corridor, set an equal distance from a benchmark located at the ROW/control edge. The ROW and control monitoring transects were placed in such a manner so as to eliminate any physiographic discrepancies between them. Each of the permitting BLM field offices were provided a copy of the monitoring plan and monitoring station locales for their review and approval in advance of any field work activity. A total of 30 permanent monitoring transects have been established within the Mojave Desert.

Each monitoring station has been permanently marked with 3/8-inch by 18-inch rebar, capped with a yellow *Permamark* plastic surveyor marker imprinted with *"Kern River"* and GPS-surveyed for ease of relocation in successive years. A line-transect/point-intercept method of data collection was followed in order to quantify ground cover that includes vegetative types, litter, rocks and biotic crusts. The associated data and plant lists will provide the basis for density and cover determinations. Qualitative observations were also included at each monitoring station and include evidence of soil disturbance; plant recruitment into the ROW; plant growth stages; invasive and noxious plants; animal use; and photographic documentation as well.

KERN RIVER RESTORATION SUCCESS AFTER FIRST GROWING SEASON

Due in part to above normal precipitation amounts during the winter of 2003/04, germination and initial seeding establishment of the reclaimed ROW corridor was observed to have a mean average plant cover of nearly 51% during the spring 2004 monitoring.

Seeding success

The reclamation monitoring during the spring of 2004 in the Mojave Desert is considered the first-growing season of the restoration effort. The primary focus for the first year's monitoring was on soil stabilization and seedling establishment. Vegetative diversity and plant recruitment should be considered in post-construction years two through five. Overall and within the California portion of the Mojave, the mean total ROW canopy cover is 40.6% of the control (undisturbed) areas. Two monitoring stations had the highest total cover, measured at 55% and 83%. Only 1 station had a measured total cover of 0%.

The Nevada portion of the Mojave monitoring found the mean total ROW canopy cover to be 56.9% of the control (undisturbed) areas. Two monitoring stations had the highest total cover, measuring 80% and 105% as compared against the undisturbed control areas. Only 1 station had a measured total cover of less than 20%. This location is associated with a pelletized seeding zone. For Utah, the northern most reach of the Mojave Desert monitoring, was found to have an 80% mean total ROW canopy cover compared against the control (undisturbed) location.

First year results of the pelletized seed demonstration areas found the use of pelletized seed to be less successful than standard seeding applications, although delayed germination in the next growing season is anticipated. One factor that may have affected the first year pelletized seed success is that thick coatings may inhibit germination and root emergence, especially with delicate-rooted plants. Insufficient soil moisture can also prevent the applied coat from breaking down and thus keeps the seed from imbibing water (Lippitt, 1992). Table 1 presents the first years monitoring findings in relationship to the restoration method used at the specific monitoring station.

Table 1. Seeding success in the Mojave Desert

Milepost	Seed mix	Monitoring station	Restoration method	% Total cover[a]		% Cover difference[b]
				ROW	Control	
428.5	UT-4	UT-1	broadcast, harrow	16	20	80
446.75	NV-1	NV-7	broadcast, imprint	24	32	75
454.5	NV-1	NV-6	broadcast, imprint	36	60	60
473.85	NV-1 (quailbrush included)	NV-5	imprint, drill	20	76	26
547.1	NV-1	NV-4	decompact, drill, imprint	48	60	80
558	NV-2	NV-3	decompact, roughen, broadcast, imprint	28	80	35
558.5	NV-1pell	NV-2	decompact, roughen, broadcast pelletized mix	8	48	17
565.5	NV-1	NV-1	decompact, roughen, broadcast, imprint	80	76	105
592	CA-4	CA-7	decom/roughen, broadcast (rate × 2), rake seeds	24	48	50
598.1	CA-4	CA-6	decompact, broadcast, imprint	16	48	33
624.5	CA-1	CA-5	decompact, broadcast, imprint	20	24	83
649.55	CA-1	CA-4	decompact, broadcast, imprint	0	40	0
9.75	CA-1	CA-1	decompact, broadcast, imprint	24	80	30
19.75	CA-2	CA-3	disk, drill, imprint	40	72	55
40.7	CA-2pell	CA-2	disk, broadcast, imprint pelletized mix	20	60	33

[a]Total cover includes canopy and basal.

[b]Cover difference is basis for meeting success standards.

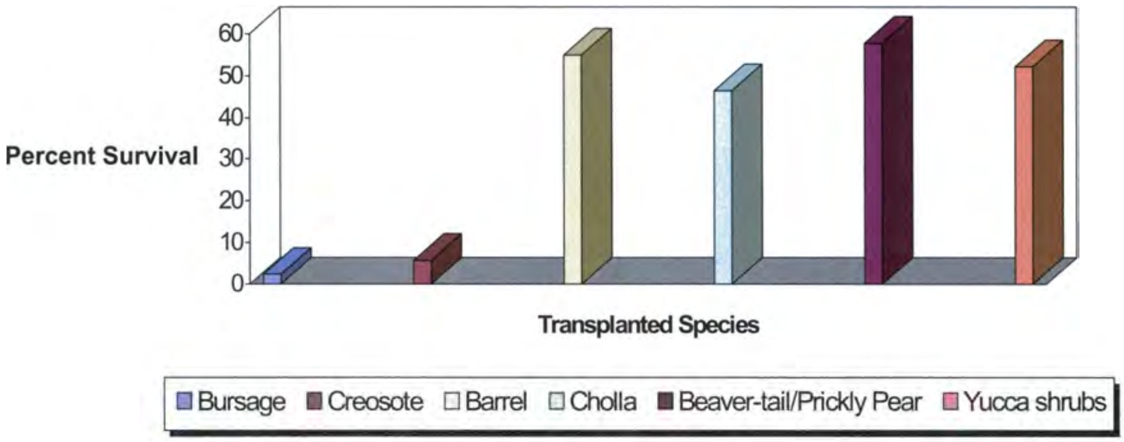

Fig. 6. Apparent vegetative survival one-year post transplanting.

Transplant success

The graph below (Fig. 6) presents apparent survival rates of the vegetative transplants, as measured during the first year post-construction. The survival percentages are based on the mean for each individual species listed. As shown, it is apparent that the cacti group had the highest survival rate. This group includes barrel cacti in the genera *Ferocactus* and *Echinocactus*, Cholla cacti in the genus *Cholla*, and beaver-tail or prickly pear cacti in the genus *Opuntia*. Yucca shrubs (*Yucca sp.*) also out-performed the deciduous shrub species, which include creosote bush (*Larrea tridentata*) and bursage (*Ambrosia dumosa*). Overall, the mean survival percentage for each planted species ranged from 2.33% for bursage to 57.8% for beaver-tail/prickly pear. Creosote bush had a 5.72% survival rate and was one of the most heavily transplanted species having nearly 1,545 total plants. The barrel and cholla cacti were each observed to have a nearly 55% and 46.5% survival rate respectively. Although yucca shrubs were not planted at all locations, nearly 330 plants were replaced after construction, with nearly 52% of these surviving the first year.

It is noted that while some survival percentages appear low, some transplanted species, such as blackbush and yucca, can exhibit apparent mortality or die-back, and then recover the following growing season under periods of more favorable moisture conditions (Plath and Heffernan, 2003). Table 2 presents selected roadway crossing data where transplants were placed on the ROW.

CONCLUSIONS

The Kern River 2003 Expansion Project involved the direct seeding of about 4,300 acres of ROW over a 320-mile section of the Mojave Desert from southern

Table 2. Transplant success in the Mojave Desert in 2004

Mile post (*highway*)	Survey area (sq. ft.)	Vegetative transplants	Number planted (*June 2003*)	Number living (*April 2004*)	Survival (%)
502.5 (93)	13,750	Yucca	unknown	7	–
		Opuntia		2	–
		Cholla		10	–
492 (111)	14,175	Yucca	35	9	25.7
		Cholla	32	18	56.25
		Opuntia	3	3	100
		Creosote	112	6	5.36
		Bursage	195	1	0.51
		Barrel	1	0	0
485 (106/122)	13,500	Cholla	20	9	45
		Yucca	60	42	70
		Opuntia	10	4	40
		Barrel	5	3	60
		Creosote	113	1	0.88
		Bursage	196	0	0
476 (92) (Hidden Valley)	14,076	Opuntia	9	4	44.4
		Saltbush	0	1	–
		Creosote	121	3	2.48
		Barrel	1	3	3
		Cholla	32	17	53.1
		Bursage	219	1	0.46
475 (168)	17,334	Bursage	340	6	1.76
		Creosote	200	2	1
		Cholla	52	31	59.6
		Barrel	6	4	66.7
		Opuntia	2	1	50
464.7 (76)	21,060	Creosote	129	5	3.86
		Bursage	239	27	11.3
		Opuntia	17	12	70.6
		Barrel	15	9	60
		Cholla	19	15	78.9
459 (66)	49,365	Cholla	76	42	55.3
		Yucca	55	27	49.1
		Opuntia	10	10	100
		Barrel	3	3	100
		Bursage	397	8	2.02
		Saltbush	0	2	–
		Creosote	230	10	4.35
455.5 (71)	16,929	Cholla	55	39	70.9
		Opuntia	2	1	50
		Yucca	32	22	68.8
		Bursage	289	4	1.38
		Creosote	156	3	1.92
		Saltbush	0	1	–
454.1 (70)	19,305	Cholla	58	24	41.4
		Barrel	2	2	100
		Opuntia	3	2	66.7
		Bursage	351	3	0.85
		Creosote	204	1	0.49
		Yucca	33	14	42.4
453.5 (69)	9,315	Cholla	43	13	30.2
		Opuntia	1	0	0
		Yucca	59	45	76.3
		Creosote	89	1	1.12
		Bursage	185	5	2.70

Table 2. (continued)

Mile post (*highway*)	Survey area (sq. ft.)	Vegetative transplants	Number planted (*June 2003*)	Number living (*April 2004*)	Survival (%)
453 (68)	4,860	Cholla	28	5	17.9
		Opuntia	5	4	80
		Yucca	9	6	66.7
		Creosote	33	10	30.3
		Bursage	104	3	2.88
452 (67)	2,718	Creosote	54	6	11.1
		Bursage	38	1	2.63
		Cholla	17	11	64.7
		Yucca	6	4	66.7
		Opuntia	2	2	100
439 (45)	12,150	Cholla	39	12	30.8
		Opuntia	4	2	50
		Barrel	2	1	50
		Yucca	41	23	56.1
		Creosote	104	6	5.77
		Bursage	209	3	1.44

Utah, across Nevada, and into Kern County, California. It also involved the replanting of some 100,000 plants. Total costs for this restoration work was approximately $15,000,000. Of this total, $5,000,000 was for direct seeding and $10,000,000 was related to plant salvaging and transplanting.

Based on the 2004 monitoring results, there was an average of 51% vegetative cover upon the Project ROW in comparison to the undisturbed reference areas. The first years findings indicate the initial success of the restoration program, as instituted by KRGT, is proceeding well toward meeting the overall success criteria established for year 6 of the restoration monitoring effort. Similarly, the success of the salvage and transplanting of succulent plants appears adequate, although the apparent survival of woody plants was low. In general, the ROW re-contouring effort and erosion control measures installed appear to be contributing greatly to the success and effectiveness of the overall ROW restoration program.

Whereas many factors may influence restoration success in a desert region, including continued third-party disturbance or poor grazing practices for which Kern River has limited or no control as an easement holder, the overall success of the KRGT restoration program shows significant promise based on monitoring results during the first full growing season after construction. However, these observations need to be tempered, recognizing that more firm conclusions on restoration success can only be made after a number of growing seasons in a desert ecosystem.

The Project in all likelihood represents the largest application of desert revegetation techniques under more natural conditions and variation that has been implemented on a linear project in recent years, as opposed to single projects on individual tracts of lands for special land uses under more controlled conditions where more intense maintenance becomes feasible. Undoubtedly, the Kern River 2003 Expansion Project will yield much more significant findings and applied experience useful to industry, land management agencies, regulators, natural resource managers, and landowners in general in the coming years.

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REFERENCES

Artz, M.C. 1989. Impacts of linear corridors on perennial vegetation in the East Mojave Desert: implications for environmental management and planning. Natural Areas Journal, 9(2): 117–129. powerlines/ohv/pipeline/road.

Bureau of Land Management (BLM), Las Vegas Field Office. November 2001. Restoration Success Standards and Monitoring Plan (Draft). Las Vegas, Nevada.

BLM, California Barstow Field Office. 2002. *Standard Seeding Guide*. Barstow, California.

BLM, California Desert District Office. 1992. Environmental Assessment for the Proposed Morongo Basin Pipeline Project, Right-of-Way Application and Proposed Exception to the Utility Corridor Element of the California Desert Conservation Area. Riverside, California.

Bainbridge, D.A. February 21, 2002b. Personal communication from Mr. Bainbridge, Researcher and Professor at Alliant International University, to Sara McMahon, Ecology and Environment, Inc., Arlington, Virginia.

Bainbridge, D.A., Robert MacAller, M. Fidelibus, R. Franson, A. Christina Williams, and Laurie Lippitt. September 1995a. *A Beginner's Guide to Desert Restoration*. Online at: URL: http://www.mycorrhiza.com/downloads/Bainbridge.pdf, accessed February 18, 2002 and September 1, 2004.

Bainbridge, D.A., M. Fidelibus, and R. MacAller. 1995b. Techniques for plant establishment in arid ecosystems. Restoration and Management Notes, 13: 190–197.

Bainbridge, D.A. November 1994. *Vertical Mulch for Site Protection and Revegetation*, online at Desert Lands Restoration Task Force: Restoration in the California Desert Website URL: http://www.serg.sdsu.edu/SERG/techniques/erosion.html, updated March 17, 1995.

Bainbridge, D.A., N. Sorensen, and R. Virginia. 1993. Revegetating desert plant communities. pp. 21–26. In Landis, T. coord. Proceedings of the Western Forest Nursery Association Meeting, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins. GTR RM-221.

Bauder, E. and A. Larigauderie. 1991. *Rehabilitation Success and Potential of Mojave and Colorado Desert Sites*. Biology Dept. for State Department of Parks and Recreation OHMVRD, SD, CA, 77 p.

Dixon, R.M. 1994. Land Imprinting for Low-cost Revegetation of Degraded Land. *Erosion Control*, July/August: 38–43.

Dixon, R.M. 1990. Land Imprinting for Dryland Revegetation and Restoration. In: *Environmental Restoration: Science and Strategies for Restoring the Earth*. Edited by J.J. Berger, pp. 14–22. Island Press, Washington, D.C. techniques/restoration.

Dixon, R.M. 1988. Land Imprinting for Vegetative Restoration. In: *Restoration and Management Notes* 6:24–25.

Fairbourn, M.L. 1975. *Field evaluation of microwatersheds and vertical mulch systems*. pp. 233–243. In Frasier, G.W. ed. Water Harvesting Symposium, Phoenix Arizona. Agricultural Research Service ARS W-22, Berkeley, CA.

Fidelibus M. and D.A. Bainbridge. July 1993. *Jellyrolling has a Potential for Reducing Outplanting Costs in Desert Revegetation Projects*. Prepared for the California Department of Transportation, District 11, 2829 Juan Street, San Diego, CA 92186, as part of the Desert Plant Project. Online at the Soil Ecology and Restoration Group Website, URL: http://www.serg.sdsu.edu/SERG/techniques/jellyroll.html, updated May 3, 2001.

Franson, R.L. and D.A. Bainbridge. 1993. Unique Revegetation Program at Mojave Desert Gold Mine Eases Environmental Concerns (California). In: *Restoration and Management Notes*, Volume 11(2), Winter 1993.

Lippitt, L.X. 1992. X-ray analysis of seed from Red Rock Canyon State Park, notes for San Diego State University/California Department of Parks and Recreation SDSU/CDP&R 8/92.

Lovich, J.E. and D.A. Bainbridge. 1999. Anthropogenic Degradation of the Southern California Desert Ecosystem and Prospects for Natural Recovery and Restoration. *Environmental Management*, Volume 24, No. 3, pp. 309–326.

Mason, J. 2001. Restoration of Damaged Lands at the National Training Center. In: *Restoration and Reclamation Review*, Vol. 7.

McMahon, Sara, Brent Arnold, Tim Powell, George Welsh, and Mike Donnelly. 2004. Restoration on a Pipeline Right-of-Way in Red Rock Canyon National Conservation Area, Nevada. in: Proceedings 8th International Rights-of-Way Symposium, School of Environmental Science and Forestry, Syracuse, NY.

Mull, Thomas. February 13, 2002. Edwards Air Force Base. Personal communication with Sara McMahon, Ecology and Environment, Inc., Arlington, Virginia.

Plath, Steven and Lisa Heffernan. Bitterroot Restoration. March 29, 2003. Personal Communications with G. Welsh, Ecology and Environment, Inc. Castle Mountain Mine, Search Light, California.

Rodgers, Jane. February 19, 2002. Joshua Tree National Park, Supervisory Resource Management Specialist and member of the Desert Managers Group. Personal communication with Sara McMahon, Ecology and Environment, Inc., Arlington, Virginia.

Scofield, Russell. February 12, 2002. Desert Managers Group. Personal communication with Sara McMahon, Ecology and Environment, Inc., Arlington, Virginia.

SERG. 2000a. *Fort Irwin – Plant Community Restoration*. Online at Soil Ecology Restoration Group Website, URL: http://www.serg.sdsu.edu/SERG/restorationproj/mojave%20desert/ft_irwin/fipcresults.html, updated July 17, 2000.

SERG. 2000b. *Revegetation Project at Marine corps Air Ground Combat Center at 29 Palms, California*, Soil Ecology Restoration Group Website, online at URL: http://www.serg.sdsu.edu/SERG/restorationproj/mojave%20desert/29palms.html, updated July 5, 2000, accessed February 25, 2002 and September 1, 2004.

SERG. 1998. *Fort Irwin - Damaged Land Restoration Research*. Online at the Soil Ecology and Restoration Group Website, URL: www.serg.sdsu.edu/SERG/restorationproj/mojave%20desert/ft_irwin/fidamlan.html, updated April 22,1998, accessed February 20, 2002 and September 1, 2004.

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