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

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

## 24–26 February 1997
## New Orleans, Louisiana, USA

*Edited by*:
James R. (Randy) Williams
John W. Goodrich-Mahoney
Jan R. Wisniewski
Joe Wisniewski

*Sponsored by*:
Entergy Services, Inc.
Electric Power Research Institute

*with support from*:
American Cyanamid Company
Edison Electric Institute
Gas Research Institute
New York Power Pool

*Conference Co-Chairmen*:
James R. (Randy) Williams
John W. Goodrich-Mahoney

ELSEVIER
SCIENCE LTD

UK ELSEVIER SCIENCE LTD
The Boulevard
Langford Lane
Kidlington
Oxford OX5 1GB, UK

USA ELSEVIER SCIENCE INC.
655 Avenue of the Americas
New York, NY10010, USA

JAPAN ELSEVIER SCIENCE JAPAN
1-9-15 Higashi-Azabu
1-Chome Minato-Ku
Tokyo 106, Japan

---



First Edition 1997

**Library of Congress Cataloging in Publication Data**
International Symposium on Environmental Concerns in Rights-of-Way
Management (6th : 1997 : New Orleans, La.)
The sixth International Symposium on Environmental Concerns in Rights-of-Way Management : 24-26 February 1997, New Orleans. Louisiana / edited by James R. (Randy) Williams ... Yet al." ; sponsored by Entergy Services, Inc. Yand" Electric Power Research Institute ; conference co-chairmen: James R. (Randy) Williams, John W. Goodrich-Mahoney.
p. cm.
Includes index.
ISBN 0-08-043 198-4 (hc)
1. Public utilities--Right of Way--Management--Congresses.
2. Environmental protection--Congresses. I. Williams, James R. (James Randy) II. Entergy Services. III. Electric Power Research Institute.
HD242.9.I58 1997
333.7 --dc21 97-15931
CIP

**British Library Cataloguing in Publication Data**
A catalogue record for this book is available from the British Library.

ISBN 008 0431984

*Printed and bound in Great Britain by Redwood Books*

# Preface

The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management is the latest in a series begun at Mississippi State University in 1976 and subsequently held at Ann Arbor, Michigan in 1979; San Diego, California in 1982; Indianapolis, Indiana in 1987; and Montreal, Quebec, Canada in 1993. The Sixth International Symposium was sponsored by Entergy Services, Inc. and the Electric Power Research Institute with support from the American Cyanamid Company, the Edison Electric Institute, the Gas Research Institute, and the New York Power Pool, and was organized in association with a steering committee representing industries, agencies and universities concerned with research and management of electric, highway, pipeline, and railroad rights-of-way.

The management of rights-of-way by electric and telephone utilities, highway departments, gas pipeline companies, and railroads around the world is guided and constrained by policies and regulations to protect the environment. In their efforts to comply with these regulations, companies are seeking the most cost-effective management practices which, at the same time, demonstrate stewardship of the environment. Protection of biodiversity and sustainable development are especially important as national goals in many countries, and rights-of-way managers are seeking practical ways to include public participation in their operations.

The Sixth International Symposium addressed environmental issues in rights-of-way planning and management, and provided a forum for information exchange among various agencies, industries, environmental consultants, and academic organizations. The Symposium provided a research update and achieved a better understanding of current environmental issues involved in rights-of-way management, focusing on these specific topics: Biodiversity, Cultural, Erosion Control, Geographic Information Systems, Project Planning, Public Involvement, Roads, Vegetation Management, Wetlands, and Wildlife.

Overall, we feel the objectives have been met. Of the 80 presentations made at the symposium, this book contains 63 peer-reviewed papers.

# Acknowledgements

We acknowledge the contributions of all paper and poster presenters for this Symposium, as well as all individuals who served as technical reviewers for the papers. We further acknowledge the efforts of all of the session chairpersons who kept the discussions active and assured their completion in a timely manner.

We acknowledge the main sponsors, Entergy Services, Inc. and the Electric Power Research Institute, and appreciate support from the American Cyanamid Company, the Edison Electric Institute, the Gas Research Institute and the New York Power Pool. We acknowledge the members of the steering committee: Larry Abrahamson, Dale Arner, Edward Colson, G. Jean Doucet, Kenneth W. Farrish, Joel Mazelis, Kevin T. McLoughlin, Dean Mutrie, Charles E. Rowell, Teresa Serra, W.S. (Bill) Scott, Richard Skarie, Jorge Roig Sóles, Gus Tillman and Ted Williams.

We also, respectively, acknowledge the commitment of resources and administrative support of Chris Longinotti and Marlene Andrews of Entergy Services, Inc. Finally, we appreciate the flawless efforts of The New Orleans Riverside Hilton Hotel; most specifically Wesley R. Galli and Jennifer B. Otis.

## Dedication

The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management is dedicated to the memory of Elmyra "Myra" Fraser of the Electric Power Research Institute. Ms. Fraser managed the planning and design for the call for papers and other activities leading up to the production of the Preliminary Program.

Ms. Fraser passed away on 24 September 1996 after a long struggle with cancer.

# Table of Contents

## Part V. Cultural



## Part VI. Wildlife



## Part VII. Biodiversity

## Part VIII. Geographic Information Systems



## Part IX. Wetlands



## Part X. Erosion Control



## Part XI. Pesticides

# Part I
# Symposium Summary Statement

# The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management —- Summary Statement

John W. Goodrich-Mahoney, James R. Williams, Dale H. Arner, Kevin T. McLoughlin, Dean Mutrie, Jan R. Wisniewski, and Joe Wisniewski

The Symposium entitled "Sixth International Symposium on Environmental Concerns in Rights-of-Way Management" was held in New Orleans, Louisiana, USA during 24–26 February 1997. This paper provides the highlights from both the presentations/papers and the discussions throughout the Symposium; including vegetation management, wildlife, biodiversity, wetlands, erosion control, pesticides, cultural, roads, project planning and geographic information systems (GIS). A background of the past five Symposia is included illustrating important historical changes and research highlights.

*Keywords*: Rights-of-way, vegetation management, project planning, wetlands, wildlife, biodiversity, roads, erosion control, pesticides, cultural

## BACKGROUND AND TRENDS IN RIGHTS-OF-WAY RESEARCH AND MANAGEMENT

The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management provided an opportunity for individuals to come together to exchange information on the planning and management of rights-of-way (ROW). The Symposium was international in character, with fourteen countries represented though presentations and posters, covering research in electric utility powerline, gas pipeline and road ROWs. This Symposium built on prior Symposia, the first of which was held in 1976 and subsequently approximately every four years thereafter, but also reflected current changes in research directions as new issues have come to the forefront and older issues have matured.

### Rights-of-way route selection

Arner (1997) noted in his keynote address that a review of the papers from the prior Symposia (Arner and Tillman 1976, Arner and Tillman 1979, Crabtree 1984, Byrnes and Holt 1987, Doucet, Seguin and Giguere 1995) shows a major decline in research efforts devoted to route selection for electric utility transmission lines. Approximately, a third of the papers presented at the first three Symposia dealt with this issue. These early papers addressed computerized modeling and methodologies for ROW selection. By the fourth Symposium, papers dealing with route selection had declined to less than a quarter of the papers presented, and by the fifth and sixth Symposia, this subject was represented by only a few papers.

### Rights-of-way vegetation development and maintenance

Rights-of-way vegetation development and maintenance has been a major topic at all six Symposia, ranking either first or second in reported research efforts. The early Symposia dealt mainly with vegetation management in electric utility powerline ROWs; at later Symposia, gas pipeline and highway roadside vegetative management papers and discussion increased. The impact of ROW maintenance treatments on wildlife habitat enhancement were included in all Symposia.

Chemical treatment to suppress undesirable vegetation has been the most frequently reported method in ROW maintenance in all six Symposia, with the emphasis declining in the more recent Symposia. Pioneer work by Egler (1975) in developing vegetation configuration on electric utility powerline ROWs apparently influenced a number of researchers, as this approach to ROW management was a central theme in their reported research in early Symposia.

### Rights-of-way construction and maintenance

The impact of ROW construction and maintenance on wildlife and wildlife habitat constituted a large portion of the papers reported in the first two Symposia. Wildlife papers, however, progressively declined in the following Symposia. The subject matter dealing with effects on wildlife did not show any discernible trends from the first through the sixth Symposia. There has been a wide spectrum of other subjects discussed in the past Symposia, which depended on the current topics of interest, ranging from collision of migrating birds with overhead transmission lines to habitat enhancement. Response by mammals and birds to ROW development and maintenance techniques was reviewed and discussed in papers at past Symposia. A number of papers presented at the fourth and fifth Symposia dealt with the impact of pipeline construction on stream fauna, and wetland flora and fauna. Papers on visual aesthetics did not reach a significant level until the fifth Symposium

### Relevant issues minimally addressed

Although mechanical cutting has been one of the most widely used techniques in ROW management, there is a noticeable paucity of information reported in the six Symposia. The use of overseeding and fertilizing on different ROW maintenance treatments has been largely neglected, and in only the early Symposia was the use of soil amendments evaluated through in-depth studies. Although fire historically has been used to reduce woody vegetation and enhance grass/herbaceous vegetation, only two in-depth studies on the subject were reported in the early Symposia. There is also a scarcity of well-designed studies addressing the role of allelopathy, the suppression of growth of one plant species by another due to the release of toxic substances, for the control and maintenance of vegetation on ROWs.

## HIGHLIGHTS OF SIXTH INTERNATIONAL SYMPOSIUM

### Vegetation management

As a matter of public safety and system integrity, the owners and operators of various types of ROWs have a continuing need to control the type and density of vegetation occupying their ROWs (Johnson 1997). This long-term vegetation maintenance requirement of ROWs involves numerous environmental and other concerns ranging from aesthetic considerations to the utilization of herbicides and their potential effects on wildlife and their habitats, to the control of non-point sources of water pollution. Additionally, ROW management activities usually are guided and constrained by policies and regulations developed by federal and state regulatory agencies, and affected groups are interested in collecting good data to support regulatory development and other activities (Norris 1997).

The greatest number of papers presented at this Symposium had "Vegetation Management" as their central topic or as a peripheral theme. The first Symposium session entitled "Integrated Vegetation Management" (IVM), was composed of papers concerning this new holistic approach to the management of ROW vegetation, which borrows from the agricultural development of Integrated Pest Management (IPM). IPM balances the use of cultural, biological, mechanical and chemical procedures for controlling undesirable plants, mainly in tall-growing vegetation in the ROW. The history of ROW vegetation management in New York was discussed by Jackson (1997), Morrow (1997) provided the basic theoretical concepts of applying IPM to the management of ROW vegetation, and McLoughlin (1997) described its practice in New York State.

The theme of a number of papers was the establishment of low-growing desirable plants, such as old field vegetation, as a technique to help preclude the growth and development of tall-growing trees, and to add to the species diversity on the ROW and to provide increased wildlife food and cover values. Assessing the effects of routine ROW maintenance activities was another environmental concern covered. The effects of ROW vegetation management upon wetlands and endangered species were of utmost concern to ROW managers, as evidenced by papers presented on these environmental regulatory topics. Economic evaluations of ROW vegetation management programs and their effectiveness in removing the target species are of continued general interest.

The ROW vegetation dynamics (Jackson 1997) that occur are only, in part, attributable to the vegetation management techniques performed. Understanding this will enable the ROW manager to better utilize natural ecological trends and identify those advantageous aspects of plant competition and successional tendencies for a successful long-term, least-cost and environmentally compatible ROW vegetation management program. To accent the international presence at this Symposium, two papers from abroad were devoted exclusively to the general topic of vegetation management under electric power lines, as currently practiced in two locations in Europe [Spain (Camacho 1997) and Austria (Draxler 1997)].

One of the most important aspects of this Symposium, was the opportunity to gain a better understanding of the current trends and new techniques available for ROW vegetation management. Two new ROW vegetation management techniques stood out for their innovative application of previously used materials or methods.

Herbicides have been used for years by ROW vegetation managers to control the regrowth of incompatible species. Over the years, more selective application techniques have evolved that reduce the volume of herbicides required to effectively subdue troublesome species. The latest "volume reducing" herbicide delivery method was the herbicide wiping technique, which combines a mechanical method of physically "scratching" the tree stem while applying a minimal dose of chemical in a highly efficacious and cost-effective treatment (Anderson 1997).

Another ROW vegetation management method discussed that was entirely mechanical in nature, involved the control of laterally rooted target species with the use of deep-blade plowing that can be used in rock free sandy soil. First, mowing of the ROW occurs to physically remove the above-ground portions of the target species. This is followed by the "plowing" operation, which involves a curved blade that severs the lateral root systems. After this below-ground root cutting action, the normal regrowth by root suckering and/or stump sprouting is reduced substantially due to this severe disturbance of the root system. Unlike other "plowing" operations, such as shear-dozing, the relatively thin blades entering the soil in this procedure produces only a minimum amount of surface soil disturbance and thus the potential for erosion and the production of sediment, a major component of non-point source water pollution, is curtailed.

Innovative research also is being conducted to develop small stature trees through controlled hybridization (Pellett 1997) for certain ROW applications that may find its greatest potential to be compatible tree growth along and under electric utility transmission and distribution lines.

### Wetlands

Designing, building and maintaining ROW projects throughout wetland areas of all types has and will continue to pose special environmental concerns for ROW managers. Many wetland ecosystems can be especially sensitive to construction and maintenance activities, while others have shown a strong capacity to recover naturally from such activities. For some wetlands, there may be little indication of effects on habitat initially following construction; however, monitoring of the environment may show long-term effects due to hydrologic modifications. McMullen (1997) compared different wetland planting mixtures and techniques used within a newly constructed gas pipeline ROW, including allowing the ROW to recover without manipulation. After three years, all study areas contained the same species, regardless of treatment, and matched the control area in species composition and abundance. McMullen suggests that in certain wetland habitats, the cost and effort to promote custom seeding is unwarranted; rather, it may be more cost effective to store the topsoil to one side during construction and replace and grade properly following construction.

Gaskin (1997) discussed two different clearing methods (machine versus hand-cleaning) used in wetlands for constructing an electric utility transmission line. The study compared the use of a low-ground pressure equipment method and a typical upland clearing timber method where vegetation is grubbed, shear-piled, burned, and disked. Change to wetland functions were measured using the Corps of Engineers' newest wetland classification system, known as the Hydrogeomorphic Functional Assessment Method (HGM). The study concluded that the greatest change to wetland functions occurred with the upland clearing method. The low-ground pressure equipment method resulted in small increases in soil temperature, lower decreases in soil macroporosity and more rapid vegetation recovery. Gaskin concluded that the low-ground pressure equipment method can be cost-effective during the dry season on a wetland that has a seasonal water table drawdown.

### Wildlife

Sheridan (1997) suggests that ROWs are refugia for rare or threatened plant species. Historically, fire suppression, beavers and various vegetation management techniques have adversely affected rare plants. This study examined numerous ROWs in Georgia, Virginia and Maryland and found that many rare plant species are confined exclusively to utility ROW. Sheridan reports 57 rare plants in 53 ROW locations, with 10 rare plant species found in a small area of a single ROW in Virginia. Routine maintenance of ROW such as selective removal of competitive species, mechanical and chemical treatments and physical disturbances all favor many species of rare plants. Rare plant species benefit by tree and shrub clearing, which generally result in early successional conditions. However, the use of chemicals can dramatically reduce the presence of rare plants in some areas. In one instance, where broadcast chemical spraying was used for clearing vegetation, it took 10 years for a rare plant population to recover to pre-spray conditions.

### Project planning

During the planning stage for ROW projects, costs to be incurred is of prime importance. Environmental, social and cultural factors can significantly affect project costs, and there are many different ways of assessing and addressing these types of costs. It is clear that early public participation in the planning process is a key to reducing cost. An open dialogue with a diverse group of stakeholders well before construction commences will reduce project delays and cost overruns.

Santos (1997) discussed how resettlement of individuals was conducted for a planned hydroelectric facility. The key to success was individual treatment and follow-up. Each affected individual had an option of direct payment or resettlement to predetermined locations. In establishing the resettlements, attention was paid to reconstructing the new surroundings to match the displaced individuals' social, economic, organizational and cultural networks. In a more general presentation, Scott (1997) reviewed a team building approach that involved industry, government and landowner interest groups in a committee designed to create a formal process of issue identification and resolution. This process led to a speed-up of the regulatory approval process. Rinebold (1997) discussed the value of life-cycle analysis, which incorporates both traditional costs and environmental considerations. This approach is gaining increasing recognition as an important decision-making tool in the evaluation of utility projects, and as a key element of future environmental management programs. Environmental life-cycle costs (i.e., all costs from purchase and use through disposal) associated with the development and operation of transmission projects were identified and discussed. Methods for evaluating and comparing costs were assessed, and recommendations were made for future use in identifying environmental life-cycle costs for transmission projects.

Jenkins (1997), Macks et al. (1997) and Scott (1997) discussed different stages in pipeline projects from planning and construction through abandonment. Jenkins (1997) discussed the third party environmental impact statement preparation process, under the United States National Environmental Policy Act (NEPA). This process offers advantages when a qualified consultant assists a Federal agency with limited funding or staff resources. Care must be taken, however, to manage the contract between the pipeline company and the consultant when the consultant is working only at the direction of a Federal agency. Jenkins noted that it is helpful to have lengthy discussions with a Federal agency prior to filing and that the filing should be as complete as possible.

Macks et al. (1997) described his Agency's compliance monitoring program and quoted statistics from five recent pipeline construction projects. While the pipeline companies had filed detailed construction plans prior to the start of construction, the companies requested 926 field changes, mostly for extra work space, off-ROW access and storage. There were also 318 non-compliance reports for infractions, such as off-ROW damages at slopes, wetlands and stream crossings. Macks, et al. noted that many of these problems could have been avoid by requesting sufficient ROW for the work; avoiding promises that can not be kept; surveying stream bottoms beforehand so it is known if the proposed crossing procedure will work; having contingency plans on hand; using experienced environmental inspectors; and not using typical drawings in special situations.

Scott (1997) discussed the concerns in Canada over pipeline abandonment. Approximately 540,000 km of pipelines currently exists in Canada. Eventually, all pipelines reach the end of their useful life, at which point, the pipeline must be abandoned in some manner. In Canada, there presently are no guidelines that address the appropriate manner of abandoning pipelines yet the regulators have identified three basic pipeline abandonment options available — removal, abandonment in place with continuing maintenance and outright abandonment in place.

With growing concern from industry and the regulators over the responsibility for abandoned pipelines, industry and government established a steering committee in 1994 to review the issue of pipeline abandonment and provide a framework for identifying, examining and providing solutions satisfactory to all stakeholders. Scott described the steering committee's work, which has been published as "A Discussion of the Environmental and Technical Issues Associated with Pipeline Abandonments". The document is available on the Canadian Association of Petroleum Producers Internet web site at http://www.capp.ca.

Mutrie and Gilmore (1997) provided an international perspective on environmental permitting for pipeline construction projects in the United States and Canada. Given the long lead times needed to obtain environmental permits and approvals, it is not uncommon for environmental personnel to be on board even before the engineering consultants have been hired. Some environmental requirements have reached the point of diminishing returns, as is evidenced by comparing requirements for pipeline construction in the United States and Canada. The United States National Environmental Policy Act (NEPA) has a new counterpart in Canada in the form of the Canadian Environmental Assessment Act (CEAA), which has introduced considerable uncertainty into the approval process for pipeline projects. To date, both countries have achieved a high degree of environmental protection, but have followed very different approaches. Mutrie and Gilmore discussed how Canada could benefit from following the United States example in protective measures for endangered species and wetlands, incorporating the environmental review process into the overall permitting process and strict enforcement of environmental requirements. The United States could follow the Canadian lead and incorporate more sophistication in soil handling techniques, streamlined procedures for dealing with cultural resources and opportunities for public involvement.

## Biodiversity

Preserving and enhancing biodiversity is a subject that is receiving increased attention in the design, construction and maintenance of ROWs. The general consensus that emerges from this Symposium is that both multiple vegetation control measures and techniques are needed to significantly increase biological diversity. Further, these multiple techniques should be quantified and the best techniques encouraged when optimization of wildlife habitat takes priority over establishing the lowest-cost/longest-term stable vegetation on ROWs.

To foster biodiversity programs, cooperation of individuals from different scientific disciplines in environmental partnerships with ROW managers is desirable. A good example of this cooperation was presented by Davila (1997). The coastal and Andean areas of Colombia have high biodiversity values and many areas are considered globally outstanding. These areas are threatened by increasing fragmentation due to access roads, and efforts are now underway to develop a biodiversity management model to address the problem. The model includes establishing a biodiversity and habitat susceptibility database to generate maps that will assist in powerline route selection, as part of the environmental impact assessment process.

Holman (1997) illustrated how the electric utility industry in the State of Kentucky played, and continues to play, an important role in formulating biodiversity policy and strategies. Electric utilities were represented on the State's Biodiversity Task Force, which prepared a report on the Biodiversity of Kentucky. One important contribution to date is a plan to collect seeds of native vegetation on existing ROWs and distribute the seeds to the State highway department and soil conservation groups for planting.

Shaw (1997) presented results of a biodiversity survey conducted by the State of Maryland, which resulted following discussions at a recently held biodiversity conference (Mattice et al. 1996). Most respondents (i.e, electric utility regulatory and natural resource agencies in each state) felt that biodiversity was an important issue. There also was consensus that managing for biodiversity will become more important in the future. The State of Maryland is taking a proactive role by developing information and manuals to assist utilities in improving biodiversity efforts.

### Roads

Highway construction and maintenance projects are increasingly employing the principles of landscape design to enhance results and minimize environmental effects. These designs employ the philosophy that roads should not only serve as a conveyance, but should enhance the aesthetics for motorists and users of the surrounding land. In a 78-km project constructed by Cofiture in central France (Galet 1997), the landscape was classified into preferential views from the perspective of the driver. These views were enhanced by selected plantings both on and off the ROW. Responsibility for managing the off-ROW plantings will be the responsibility of the landowner after four years, with the expectation that most landowners will continue to maintain, or at least not remove, the plantings. Other design elements included overpasses for upland wildlife to prevent mortality from traffic.

Storey (1997) presented a similar approach used in a conceptual design study for a section of an urban highway in Houston, Texas. The objective of the design was to create a sense that it is more than just a highway by integrating landscaping and other uses. Space for additional high-occupancy vehicle lanes was obtained by replacing sloped concrete sides with a combination vertical retaining wall and sound barrier. Hiking and bike trails were placed outside the retaining wall/sound barrier to facilitate multiple use of the easement. Transparent materials in the sound barrier provided a visible connection across the highway for users of the trail.

Harper-Lore (1997) discussed how the Federal Highway Administration, in an effort to implement a 1994 Executive Memorandum from the Clinton administration, is conducting educational programs to encourage vegetation managers through out the U.S.A. to adopt a more ecological approach to managing highway ROWs. The memorandum strongly encouraged federal agencies and federally funded projects to plant native species, where feasible, and to use herbicides in an environmentally responsible manner. This approach, which represents a radical departure from the "front yard" philosophy of ROW maintenance, was readily accepted by highway departments in about half of the United States. Using native species and less herbicides is seen as a way to save on maintenance costs while enhancing the natural environment, although the approach is not viewed simply as a highway beautification program.

### Summary

As we move into the next century, industries, especially electric utilities, will be challenged as a result of deregulation and the further opening of global markets. Those companies that are low-cost producers and, at the same time, can effectively balance costs with environmental protection, will be the most successful. As with any business decisions, knowledge is crucial to making good choices (Norris 1997), and the environmental arena is no exception. Research that produces relevant data is crucial to the development of better knowledge bases. Having the data removes uncertainty, increases the likelihood of acceptance of the conclusions, and will increase the quality of decisions, all of which have a direct bearing on costs. Costs for environmental protection also can be reduced through partnering and, in international operations, through a clear understanding of the social and cultural aspects of the host country (Tillman 1997).

This Symposium and the prior Symposia have addressed many major Environmental Concerns in ROW management, yet there remain many other subjects that need attention (Arner 1997). These include, for example, the use of allelopathy to control unwanted species, fertilizing/seeding of ROWs, agency/utility company cooperation, and route selection as it relates to endangered species. It is hoped that future symposia will explore these issues in more detail.

### REFERENCES

Anderson, J.R., Jr., B.G. Warsen, P.T. Bromley, and W.E. Palmer. 1997. Vegetation management in rights-of-way with a herbicide wiping technique. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Arner, D.H. 1997. Changes in research direction involving rights-of-way environment concerns in the past twenty years. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Arner, D.H. and R.E. Tillman, eds. 1976. First Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State, Mississippi.

Arner, D.H. and R.E. Tillman, eds. 1979. Second symposium on Environmental Concerns in Rights-of-Way Management. Electric Power Research Institute, Palo Alto, California.

Byrnes, W.R. and H.A. Holt, eds. 1987. Fourth Symposium on Environmental Concerns in Rights-of-Way Management. Purdue University, West Lafayette, Indiana.

Camacho, J.A., J.R. Soles, and C.M. Juaristi. 1997. Iberian flora and overhead powerlines. Paper presented at Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Crabtree, A.F., ed. 1984. Third International Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State, Mississippi.

Davila, E.A. 1997. Power lines and biodiversity in the Colombian territory. In: 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. Elsevier Science, Oxford, England.

Doucet, G.J., C. Seguin, and M. Giguere, eds. 1995. Fifth International Symposium on Environmental Concerns in rights-of-way management. Hydro-Quebec, Montreal, Quebec, Canada.

Draxler, R., D. Uther, G. Praxl, and F. Hofbauer. 1997. New aspects of Rights-of-Way Management for high voltage powerlines. In: 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. Elsevier Science, Oxford, England.

Egler, F.E. and S.R. Foote. 1975. The plight of the ROW domain victum of vandalis. Part 1. Futura Media Service, Mount Kisco, New York, 294 pp.

Galet, M. 1997. Landscape management of the A85 motorway in France. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Gaskin, J.W. and W.L. Nutter. 1997. Evaluating transmission line clearing methods for minimizing changes in wetland function. In: 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. Elsevier Science, Oxford, England.

Harper-Lore, B.L. 1997. Vegetation management: trends and training in transportation. In: 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. Elsevier Science, Oxford, England.

Holman, J. 1997. Electric utility involvement in the kentucky biodiversity council. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Jackson, L.W. 1997. A history of utility transmission right-of-way management in New York State. In: 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. Elsevier Science, Oxford, England.

Jenkins, D.F. 1997. Third-party EISs for federal approval of pipeline projects in the United States. In: 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. Elsevier Science, Oxford, England.

Johnson, F. 1997. Lessons learned from the summer 1996 blackouts in the western United States. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Macks, D.D., D. Morrell, and J. Strub. 1997. Common environmental problems encountered during construction of major gas transmission lines. In: 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. Elsevier Science, Oxford, England.

Mattice, J., M. Fraser, S. Ragone, J. Wisniewski, and J. Wisniewski, eds. 1996. Managing for biodiversity: Emerging ideas for the electric utility industry. Environmental Management, 20: 771–974.

McLoughlin, K.T. 1997. Application of integrated pest management to electric rights-of-way vegetation management in New York State. In: 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. Elsevier Science, Oxford, England.

McMullen, J., and M. Burger. 1997. Evaluation of different grasses to restore wetland and control weed species after pipeline construction. In: 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. Elsevier Science, Oxford, England.

Morrow, S.D. 1997. Effective integrated vegetation management. In: 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. Elsevier Science, Oxford, England.

Mutrie, D.F. and K.B. Gilmore. 1977. Pipelining in Canada and the U.S.: an environmental comparison. In: 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. Elsevier Science, Oxford, England.

Norris, L. 1997. Address environmental concerns with real data. In: 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. Elsevier Science, Oxford, England.

Pellett, H. 1997. Development of small stature trees for electric utility rights-of-way. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Rinebold, J.M. and L.F. Mango. 1997. Life cycle analysis for transmission line design. In: 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. Elsevier Science, Oxford, England.

dos Santos, A.F. 1997. Public participation in the resettlement program for the Salto Caxias hydroelectric project. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Scott, I.F.H. 1997. The Alberta pipeline environmental steering committee: A model for cooperative resolution of issues. In: 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. Elsevier Science, Oxford, England.

Scott, I.F.H. 1997. A discussion of the environmental and technical issues associated with pipeline abandonments. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Shaw, S.K., J.L. Magistro, and S. Collins. 1997. Resource protection through Maryland licensing requirements. In: 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. Elsevier Science, Oxford, England.

Sheridan, P.M., S.L. Orzell, and E.L. Bridges 1997. Powerline easements as refugia for state rare seepage and pineland plant taxa. In: 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. Elsevier Science, Oxford, England.

Storey, B. 1997. Gateway to the museum district: a conceptual design study Houston, Texas. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

Tillman, R.E. 1997. Environmental concerns in rights-of-way management in the international arena. Paper presented at the Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. New Orleans, Louisiana, 24–26 February.

---

## *BIOGRAPHICAL SKETCHES*

***John W. Goodrich-Mahoney***

*Electric Power Research Institute, Suite 805, 2000 L Street, NW, Washington, DC 20036, USA*

John W. Goodrich-Mahoney is a Project Manager in the Water Toxics Assessment and Watershed Management Business Area within the Electric Power Research Institute's Environment Group. He is responsible for the development and management of research to help reduce surface water and other regulatory compliance costs for the electric utility industry. Additionally, he is involved in the tracking and assessment of the effects on the electric utility industry of statutory and regulatory developments under the Resource Conservation and Recovery Act (RCRA) and the Clean Water Act (CWA). He is the author and co-author of numerous technical papers in the environmental field and is a member of the American Association for the Advancement of Science and the American Chemical Society. He also chairs an ASTM technical committee, which is developing guidance documents to support wetlands restoration, enhancement and creation. Mr. Goodrich-Mahoney received a BS degree in Chemistry and Geology from St. Lawrence University, Canton, New York and an MSc degree in Geochemistry from Brown University, Providence, Rhode Island.

***James R. (Randy) Williams***

*Entergy Services, Inc., P.O. Box 61000, New Orleans, LA 70161, USA*

James R. Williams has worked for Entergy Services, Inc. since 1980 in the area of environmental affairs. Prior to his employment with Entergy he worked for the Louisiana Department of Wildlife and Fisheries. Mr. Williams received both a BSc and an MSc degree from Louisiana Tech University in the field of Wildlife Conservation. His research focus for several years has been in vegetation management and biodiversity.

***Dale H. Arner***

*Mississippi State University, P.O. Box 9690, Mississippi State, MS 39762, USA*

Dale Arner is Department Head and Professor Emeritus at the Department of Wildlife and Fisheries, Mississippi State University. He obtained his BSc and MSc from Penn State, and his PhD at Auburn University. Interests: Applied wildlife habitat ecology. Research areas: Right-of-way and beaver pond ecology.

***Kevin T. McLoughlin***

*New York Power Pool, Empire State Electric Energy Research Corporation, 5172 Western Turnpike, Altamont, New York 12009, USA*

Kevin McLoughlin is presently the Administrator of Land Use & Industrial Waste Programs for the New York Power Pool and the Empire State Electric Energy Research Corporation. He earned his BSc and MSc degrees in Natural Resource Management at the State University of NewYork College of Environmental Science & Forestry at Syracuse University. Prior to his current position, he was the System ROW Vegetation Management and Transmission Line Construction Environmental Engineer for the New York Power Authority and served as the Supervisor Natural Resource Management Group. Mr. McLoughlin also had experience with the US Forest Service in Idaho and Arizona.

***Dean Mutrie***

*Tera Environmental Consultants (ALTA.) Ltd., Suite 205, 925 - 7th Avenue, SW, Calgary, Alberta, Canada T2P 1AS*

Dean Mutrie holds degrees in Environmental Studies from the University of Waterloo and has focused exclusively on the pipeline field since 1975. He co-founded the annual Pipeline Environmental Inspection course offered by the Petroleum Industry Training Service and has instructed numerous environmental compliance courses offered by FERC, BLM and U.S. pipeline companies.

***Jan R. Wisniewski***
*Wisniewski & Associates, Inc.*
*P.O. Box 1291*
*McLean,Virginia 22101, USA*

Jan R. Wisniewski works as an editorial coordinator for Wisniewski & Associates, Inc. She also serves as the Managing Editor for Lawrence Erlbaum and Associate's *Environmental Science: International Journal of Research & Policy*. She has received a BS in Psychology, an MA in Clinical Psychology and an MBA in Human Resources Management.

***Joe Wisniewski***
*Wisniewski & Associates, Inc.*
*P.O. Box 1291*
*McLean,Virginia 22101, USA*

Joe Wisniewski is President of Wisniewski & Associates, Inc. and an Adjunct Professor on the faculty of North Carolina State University's College of Forest Resources. He received a BA in Chemistry, BA in Mathematics, MS in Atmospheric Sciences & Oceanography, PhD in Environmental Sciences and an MBA in International Economics/Finance. Currently, he works as an environmental consultant and editorial coordinator, as Editor-in-Chief of Lawrence Erlbaum and Associate's *Environmental Science: International Journal of Research & Policy* and serves as a Special Issues Coordinator for Elsevier Science's Environmental Journals.

# Part II
# Vegetation Management

# A Review of Upland Game Habitat Management on Rights-of-Way

**Dale H. Arner**

From a perspective of 45 years of research on rights-of-way (ROW) maintenance techniques used to enhance upland game habitat in the southeastern United States at minimal costs, a review and discussion is given of several techniques. The maintenance techniques reviewed are herbiciding, burning, and use of mechanical manipulation. The results of the use of seeding and fertilizing in combination with the above-mentioned maintenance techniques are presented and discussed. The nutritional value is given of those plant species which most commonly occur in ROW developed by different maintenance techniques. Management recommendations are suggested for ROW in different southeastern ecosystems.

*Keywords*: Right-of-way, herbicide, mow, burn, upland game

## INTRODUCTION

In the southeastern United States, a great deal of effort has been expended on testing and evaluating the impact of different rights-of-way (ROW) maintenance techniques on upland game habitat. The upland game species of major consideration are the northern bobwhite (*Colinus virginianus*), the eastern wild turkey (*Meleagris gallopavo*), and the white-tailed deer (*Odocoileus virginianus*). Most research efforts have centered on using herbicides, while less research effort has been put into burning, fertilizing, seeding, and mechanical methods. The purpose of this paper is to review and present pertinent information derived from working with the above-mentioned techniques for a period of over 45 years. Various maintenance techniques are reviewed, and nutritional information is presented.

## HERBICIDE USE

Herbicides are widely used to keep electric transmission lines free of woody vegetation. They are readily available and easily applied. There is, however, a growing concern about the danger such chemicals may have on human health, and the hazard posed from run-off into streams and lakes, as well as underground water. The best approach in using herbicides is to use them sparingly, and to use those which do not leave residual toxicity for legumes. It should be recognized that herbicides do not have the same positive impact on germination of many species of herbaceous plants as fire and mechanical practices do.

In the southeastern U.S., ROW which have been treated with 2,4,5-T (trichlorophenoxyacetic acid) (Thorn 1972; Huntley 1977) or Roundup (isoprolamine glyphosphate) (Hartley 1982) developed fewer legumes than burned, disked, or mowed ROW. Reduction of the number and coverage of legumes adversely impacts bobwhite habitat. Stoddard (1932) wrote that legumes are of such primary importance to bobwhites in the southeast that he relied on the abundance or scarcity of legumes as an index to quail populations of the region. The forage value to deer of many species of legumes is high due to nutritional content (Table 1).

Generally, herbicides can benefit deer and turkey more than they benefit bobwhites. The food resource of these two species can be increased by basal selective spraying of undesirable trees, e.g. pine, sweetgum, oaks, and hickories, to release and enhance growth of such fruit-producing shrubs and vines as blueberries, *Viburnum*, wild grape, green briar, and spice bush (see Table 1 for determination of nutritionally desirable deer food plants).

A long-range study at Mississippi State University (Arner, Glover, Hartley, and Huntley 1987) showed

**Table 1. Proximate analysis of some common forage plants, fruits, and seeds (reported in percent)**

| | Crude protein | Crude fiber | Crude fat | Ash |
|---|---|---|---|---|
| Forage | | | | |
| *Anisostichus* sp. | 27.1 | 29.3 | 6.0 | 5.5 |
| *Cornus florida* | 28.9 | 14.5 | 6.7 | 6.3 |
| *Ilex glabra* | 6.4 | 15.4 | 9.2 | 3.0 |
| *Ilex vomitoria* | 8.1 | 26.6 | 5.2 | 3.1 |
| *Lolium perenne* | 22.1 | 16.2 | 9.0 | 10.9 |
| *Pinus echinata* | 3.7 | 26.2 | 9.7 | 4.3 |
| *P. palustris* | 1.8 | 42.5 | 8.2 | 2.7 |
| *P. taeda* | 3.3 | 33.3 | 10.8 | 3.9 |
| *Quercus incana* | 7.0 | 27.4 | 3.7 | 3.8 |
| *Q. laurifolia* | 4.8 | 26.0 | 4.0 | 3.7 |
| *Rhus radicans* | 36.8 | 19.5 | 4.5 | 7.5 |
| *Trifolium repens* | 24.1 | 18.5 | 3.7 | 11.1 |
| *Vaccinium arboreum* | 7.4 | 25.8 | 5.8 | 3.1 |
| *V. elliottii* | 6.1 | 28.6 | 8.6 | 3.8 |
| Fruits and seeds | | | | |
| *Axonopus affinis* | 11.9 | | 2.6 | 4.0 |
| *Carya illinoensis* | 7.2 | 33.5 | 17.1 | 2.2 |
| *Celtis laevigata* | 2.9 | 13.8 | 1.1 | 55.0 |
| *Cyperus esculentus* | 7.9 | 5.3 | 21.0 | 4.8 |
| *Cornus florida* | 6.5 | 25.1 | 18.7 | 6.0 |
| *Lathyrus* sp. | 24.3 | 11.8 | 0.2 | 4.0 |
| *Lindera benzoin* | 17.9 | 2.4 | 46.2 | 5.8 |
| *Malus angustifolia* | 30.6 | 20.5 | 5.7 | 3.3 |
| *Quercus nigra* | 6.4 | 14.4 | 1.7 | 5.3 |
| *Q. lyrata* | 4.8 | | 0.7 | 2.2 |
| *Smilax* sp. | 5.7 | 15.8 | 1.5 | 4.4 |
| *Triticum aestivum* | 11.9 | | 2.6 | 2.0 |
| *Vitis* sp. | 2.5 | 28.8 | 3.1 | 6.5 |

that herbicides will be required to renovate ROW that have been maintained by mowing or burning after a period of 10–12 years. Rights-of-way in the MSU study that had been maintained either by mowing every third year or burning every second year gradually became dominated by encroaching root suckers of sweetgum and sumac. These species, along with sassafras and gallberry, respond to cutting or burning of the main stem by sending up numerous root suckers each time the stem is severely injured. After four or five ROW treatments of either cutting or burning, the greater part of the ROW becomes dominated by the suckering species, with a resulting decrease in herbaceous plants. Many of these herbaceous plants are choice food plants for upland game. With the decrease in desirable food plants, a radical reduction of the suckering species becomes necessary before a burning or mowing regime can be resumed. To accomplish this reduction, herbicides provide the most effective solution. It should be noted that when shrubs such as sumac are favored by herbicide selection, results will be the same, with the entire ROW dominated by sumac.

Herbicides applied in a selective manner can be used on hilly or rough terrain, whereas, the development of fire lanes may create erosion problems, and the roughness of terrain can create hazardous mowing conditions.

Total costs of herbicide application vary widely depending upon herbicide cost, method of application e.g. knapsack sprayer, tractor sprayer, or aerially. Current costs reported by utility companies in Mississippi ranged from $395 to $556 per ha ($160 to $225 per acre).

## USE OF MECHANICAL METHODS

### Mowing

Within the last two decades, rotary mowing has displaced hand cutting of woody vegetation on ROW, and has become a widely-used practice in ROW maintenance. Rotary mowers can cut woody plants up to 1.5 inches in diameter. The cost of mowing is competitive with that of broadcast spraying, and less than selective spraying. Mowing can be used in a selective manner, whereby undesirable plants are mowed, and desirable plants are left intact (Hartley and Arner 1982). Mowing during colder months of the year will induce sprouting of woody plants and increase palatable deer browse. In several Mississippi studies, mowing produced more desirable quail food plants than did herbicide use (Huntley 1977; Hartley 1982; Hartley and Arner 1982). These researchers also found that legumes on mowed ROW could be increased by overseeding and fertilizing, and were comparable in abundance to the burned plots.

In Alabama, a ROW maintained by previous winter mowings was characterized by mixed herbaceous openings and low resprouting brush habitat. Of the turkey nests Everett et al. (1981) found during their turkey research in north Alabama, 37% were found on this ROW, which represented less than 1% of the research area. Everett also reported that wild turkey nesting was greatly reduced on the area the first year after mowing.

Mowing of ROW is considered more favorable by utility companies for the following reasons: mowed terrain is more aesthetically pleasing to the general public than is the chemically sprayed or burned ROW, and potential risk of herbicide damage to adjacent lands is eliminated. Mowing costs vary; small local mowing operators usually underbid the larger vegetation maintenance companies. Terrain and distance from access highway also influence costs. In Mississippi in 1996, TVA reported mowing costs of their powerline ROW ranged from $124 to $198 per ha ($50 to $80 per acre).

### Disking

The disk has been used in the southeastern U.S. on ROW as a maintenance technique and to enhance upland game habitat. In a three-year study in central

**Table 2. Common and scientific names of plants**

| | |
|---|---|
| Ash | *Fraxinus* spp. |
| Beggarweed | *Desmodium* spp. |
| Birch | *Betula* spp. |
| Blueberry | *Vaccinium* spp. |
| Blue grass | *Poa* spp. |
| Brome grass | *Bromus secalinus* |
| Broomsedge | *Andropogon virginicum* |
| Browntop millet | *Panicum ramosum* |
| Cedar | *Juniperus virginiana* |
| Chufa | *Cyperus esculentes* |
| Chinquapin | *Castanea pumula* |
| Clover, red | *Trifolium pratense* |
| Clover, white | *Trifolium repens* |
| Crab apple | *Malus angustifolia* |
| Crab grass | *Digitaria* spp. |
| Dogwood, flowering | *Cornus florida* |
| Gallberry | *Ilex glabra* |
| Greenbriar | *Smilax* spp. |
| Groundsel bush | *Baccharis halimifolia* |
| Hawthorn | *Crataegus* spp. |
| Hornbeam | *Ostrya virginiana* |
| Lespedeza, Kobe | *Lespedeza striata* |
| Lespedeza, sericea | *Lespedeza cuneata* |
| Maple | *Acer* spp. |
| Mulberry, red | *Morus rubra* |
| Oak | *Quercus* spp. |
| Oak, runner | *Q. pumila* |
| Panic grass | *Panicum* spp. |
| Panicum, spreading | *Panicum rhizomatum* |
| Partridge pea | *Chamaecrista fasciculata* |
| Pecan | *Carya illinoensis* |
| Pine | *Pinus* spp. |
| Plum | *Prunus* spp. |
| Red root | *Lacnanthes tinctoria* |
| Ryegrass | *Lolium perenne* |
| Sassafrass | *Sassafras albidum* |
| Spice bush | *Lindera benzoin* |
| Sumac | *Rhus* spp. |
| Sweetgum | *Liquidambar styraciflua* |
| Vetch, hairy | *Vicia villosa* |
| Vetch, crown | *Coronilla varia* |
| Viburnum | *Viburnum* spp. |
| Wax myrtle | *Myrica cerifera* |
| Wheat | *Triticum aestivum* |
| Wild grape | *Vitis* spp. |
| Winter pea | *Lathyrus* sp. |
| Yaupon | *Ilex vomitoria* |

Mississippi, disking produced fewer desirable herbaceous food plants than mowing, burning, or selective herbiciding; however, desirable grasses were more abundant over a two-year period on disked plots than on other treatments.

Disking operations conducted during experimental studies at MSU indicated costs were slightly higher than mowing.

Stoddard (1932) used disking in broomsedge fields during late winter to increase beggarweed and bush clover. He reported a fourfold increase of these plants compared to undisked adjacent areas. However, it must be recognized that not all old fields will produce good stands of legumes by winter disking any more than similar poor soil areas will produce legumes after burning. Work by this writer has shown poor legume development in impoverished soil areas in the Lower Coastal Plain and the eroded Blackland soils of central Mississippi. Overseeding and fertilizing is again the key to successful enhancement of upland game foods on many southeastern soils of low fertility.

## Prescribed burning

Fire has played a major role in vegetational development throughout the world. Studies of the impact of fire on the flora and fauna of the southeastern states have been lengthy and controversial (Komarek 1974). It is a recognized technique to establish desirable food plants for the northern bobwhite (Stoddard 1932; Rosene 1969). Burning dense herbaceous vegetation allows quail to move about and feed (Stoddard 1932). Grasses are important foods for the wild turkey (Korschgen 1967), especially panic, crabgrass, and bluegrass. Wheeler (1948) considered fire to be the most practical tool for developing and maintaining a stand of grasses in a clearing.

## Winter burning

Plots that were winter burned on those soils which were higher in nutrient content, e.g. Piedmont soils, Upper Coastal Plain soils, Brown Loam soils, produced good stands of quail food plants. In contrast, plots burned on impoverished soils of the Lower Coastal Plain and Interior Flatwoods produced few desirable quail food plants (Arner, Cliburn, Thomas, and Manner 1976).

In a study of various treatments in two different areas in east-central Mississippi, one area that was winter burned produced significantly more quail food plants than the area with basal or aerial spraying. In the other area, winter burning did not produce significantly more quail food plants than the mowed plots (Hartley and Arner 1982).

In 1996, costs for prescribed burning by the Mississippi Forestry Commission included $50 per hour for plowing fire lanes, and $15 per ha ($6 per acre) for burning.

## Overseeding and fertilizing

Nutritional quality of upland game food plants varies widely in different plant species, in addition to, seasonally. Although utility-line ROW comprise relatively small acreage within southeastern forest ecosystems, they possess great potential to increase upland game populations by increasing habitat quality. Improving the habitat involves developing quality food and cover. Steen (1954) noted that in Missouri, wildlife populations on low fertility Ozark Mountain Range soils had doubled and tripled by fertilization and proper tillage

**Table 3. Suggested planting recommendations for the mid-south**

| Plant species | Seeding dates | Seeding rate (lbs/acre) | Cost ($/lb) |
|---|---|---|---|
| Common, Kobe, and Korean lespedeza | Mar 1–May 1 | 25–30 | 1.20 |
| Browntop millet | May 1–Jul 30 | 8–15 | 0.35 |
| Partridge pea | Dec 15–Feb 15 | 3– 5 | 8.50 |
| Hairy vetch | Sep 1–Oct 15 | 25–30 | 0.86 |
| White clover | Sep 1–Nov 15 | 3– 5 | 2.00 |

of no more than 1–2% of that range. Gardner and Arner (1968) showed that turkey hens fed on a supplemental diet consisting of white clover, chufa, wheat, and winter peas, produced nearly seven times the eggs of a group fed on a wild diet of acorns, honeysuckle, carpet grass, and brome grass.

Overseeding and fertilizing is usually needed on ROW located on nutrient-impoverished soils, or on ROW maintained by broadcast herbiciding. However, fertilizing on ROW which have remnants of desirable plant species is usually sufficient to increase by several fold the desirable plant species. If there is little evidence of desirable plant species on the ROW, fertilizing should be followed by overseeding of one, or a combination of the following species: partridge pea, Kobe lespedeza, hairy vetch, white clover, red clover, browntop millet, or rye grass (Table 3). Selecting proper food plants is dependent on the targeted upland game species. Partridge pea and Kobe lespedeza provide choice food through fall for bobwhites, while clover and rye grass provide nutritional food for turkey and deer. Hairy vetch and browntop millet are good food plants for quail and turkeys; however, vetch provides food during spring, and browntop provides summer food.

Seeding of tall fescue, sericea lespedeza, and crown vetch should be avoided. Tall fescue, widely used for waterway ditches and ROW, has little upland game food value. It is a cool-season perennial which spreads by rootstock, making it an aggressive plant that tends to crowd out more desirable plants. Sericea lespedeza is a perennial legume which produces seeds high in tannic acid and seldom used by upland game. The plant develops an extensive root system and a dense stand of vegetation, providing little space for other plants. Crown vetch also is an aggressive plant with little value as food for upland game.

## ROW MANAGEMENT TECHNIQUES

Enhancing upland game habitat on electric utility line ROW should involve plants bordering the ROW, as well as plants growing on the ROW. Trees and shrubs growing on the periphery of the ROW will develop larger crowns due to openings created by the ROW. Fruit production can be greatly enhanced by selective thinning in which undesirable trees are cut or poisoned. The species to be considered for removal are pine, birch, ash, maple, cedar, hornbeam, sweetgum, and groundsel bush. The species to be considered for saving are oaks, hickories, pecan, chinquapin, mulberry, viburnum, hawthorn, dogwood, crab apple, and plum.

To maximize upland game habitat on ROW in mixed hardwood/pine forests of the hilly to mountainous areas, roughly two-thirds of the ROW should be maintained in mixed shrub/grass openings and one-third in legume openings. The shrub/grass component can be most economically developed by selective mowing of the ROW, whereby only undesirable woody plants are mowed, with a herbicide used on the cut stobs. Native grasses and legumes will increase as the woody component decreases. Legume openings can be developed on the more level segments of the ROW by overseeding legumes (Note section on overseeding). Fertilization will enhance most seeded legumes on ROW of low to moderate fertility.

In the extensive pine forests of the Lower Coastal Plain, the need for herbaceous openings is critical for upland game. It is thus recommended that two-thirds of the ROW be developed into herbaceous openings and one-third into shrub/grass openings. Due to flat terrain, prescribed burning and disking become the more practical and economical techniques.

In the highly organic soils of pine savannahs and flatwoods, disking can be used to develop excellent stands of red-root, a perennial herb that produces abundant seed which are a good food source for upland game birds and waterfowl. Panic grasses, especially spreading panicum, frequently develop along with this species. The more moist sites in the pine flatwoods contain gallberry, which has a tendency to spread by fire. Disking must be deep and thorough to discourage gallberry, although data is not available on the disking frequency needed to control this shrub.

Fire enhances many shrubs of value to upland game, such as blueberries, runner oak, wax myrtle, and yaupon. In most of the more mesic sites where soils have developed from beds of unconsolidated sands and sandy clays, the soils will be highly acidic and low in fertility. Fertilizer is essential for successful establishment and growth of overseeded species, such as partridge pea and Kobe lespedeza on burned sites. Four hundred pounds of 0–14–14 has proven to be adequate to establish partridge pea and Kobe lespedeza on burned, impoverished soils in south Alabama (Arner, Cliburn, Thomas, and Manner 1976). It may be necessary to add lime on sites that are disked and fertilized.

In all of these ROW treatments, maximizing plant diversity should be encouraged by shifting treatments around in the ROW maintenance schedule.

## SUMMARY AND CONCLUSIONS

Herbicides are most effectively used for reduction of undesirable woody plants, and are generally detrimental to legumes. However, herbicides used in a selective manner can be used to enhance habitat for upland game. Rotary mowing produced more quail food plants than herbicide use or disking. Disking costs were higher than mowing. Winter burning produced more quail food plants than herbicide use, and cost less than the other treatments.

On soils of low fertility, overseeding and fertilizing were the key to enhancement of upland game foods. Regardless of maintenance techniques used, fertilizing and overseeding are necessary to establish desirable game food plants on nutrient-impoverished soils. Sericea lespedeza and crown vetch should not be seeded. A comprehensive review of pertinent literature indicated a paucity of information on use of fire, fertilizing, and overseeding on ROW.

Game food plant species and the percentage of ROW developed in grass/shrub or legume openings will depend on the target upland game species involved, as well as the terrain.

## REFERENCES

Arner, D.H., L.E. Cliburn, D.R. Thomas, and J.D. Manner. 1976. The use of fire, fertilizer, and seed. In: Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State. pp. 156–165.

Arner, D.H., J. Glover, D. Hartley, and J. Huntley. 1987. Vegetational changes on a right-of-way after repetitions of different maintenance treatments. In: Proceedings of the Fourth National Symposium on Environmental Concerns in Rights-of-Way Management. Purdue University, West Lafayette, Indiana. pp. 133–135.

Everett, D.D., D.W. Speake, and W.K. Maddox. 1979. Use of rights-of-way by nesting wild turkeys in north Alabama. In: Proceedings of the Second National Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State. pp. 64-1–64-6.

Gardner, D.T., and D. Arner. 1968. Food supplements and wild turkey reproduction. Transcripts of the North American Wildlife Conference, 33: 250–258.

Hartley, D.R. 1982. The effects of various maintenance techniques upon rights-of-way vegetation and wildlife utilization. M.S. Thesis. Mississippi State University, Mississippi State. 83 pp.

Hartley, D.R., D.H. Arner, and J.W. Lipe. 1982. A comparison of rights-of-way maintenance treatments and use by wildlife. In: Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State. pp. 623–629.

Huntley, J.C. 1977. The effects of several utility rights-of-way maintenance techniques upon game food plants. M.S. Thesis. Mississippi State University, Mississippi State. 95 pp.

Huntley, J.C. and D.H. Arner. 1979. The effect of utility rights-of-way maintenance upon game food plants. In: Proceedings of the Second National Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Mississippi State. pp. 31-1–31-13.

Komarek, E.V. 1974. In: Fire and ecosystems. T.T. Kozlowski and C.E. Ahlgren, eds. Academic Press, New York. 542 pp.

Korschgen, L. 1967. Feeding habits and foods. In: The Wild Turkey and its Management. O.H. Hewitt, ed. The Wildlife Society, Washington, D.C. 589 pp.

Rosene, W. 1969. The bobwhite quail, its life and management. Rutgers University Press, New Brunswick, New Jersey.

Steen, M.O. 1954. Qualitative nutrition — a game management tool. Southeastern Fish and Game Commissioner's Conference. New Orleans, Louisiana.

Stoddard, H.L. 1932. The bobwhite quail, its habits, preservation, and increase. Charles Scribner and Sons, New York. 559 pp.

Thomas, D.R. 1972. A preliminary study of various control measures for rights-of-way management. M.S. Thesis. Mississippi State University, Mississippi State. 54 pp.

Wheeler, R.J., Jr. 1948. The wild turkey in Alabama. Pittman-Robertson project report. Alabama Department of Conservation, Montgomery, Alabama. 92 pp.

### BIOGRAPHICAL SKETCH

***Dale H. Arner***

*Department of Wildlife and Fisheries,*
*Mississippi State University,*
*P.O. Box 9690,*
*Mississippi State, MS 39762, USA*

Dale Arner is Department Head and Professor Emeritus at the Department of Wildlife and Fisheries, Mississippi State University. He obtained his BS and MS from Penn State, and his PhD at Auburn University. Interests: Applied wildlife habitat ecology. Research areas: Right-of-way and beaver pond ecology.

# Environmental Impacts Associated with Routine Transmission Line Maintenance

**John M. Bridges, Mary Barger, Nick Chevance, Ted Anderson, John Holt, Rodney Jones, and Earl Nelson**

The Western Area Power Administration (Western) operates and maintains more than 17,000 miles of transmission lines in its service area of 16 western states. As an agency of the U.S. Department of Energy (DOE), each action associated with the maintenance of this system is subject to review under the National Environmental Policy Act (NEPA), and other Federal, state and local environmental laws, regulations, guidance. Routine maintenance activities range from helicopter patrols to herbicide spraying, and pole change-outs to cross-arm replacements. Each of these activities has the potential to impact sensitive resources, such as unique farmlands and soils, sensitive cultural resources, endangered or threatened species, migratory birds, or important wildlife use areas and sensitive habitats. Western has developed routine compliance methods to meet our statutory requirements and to protect the resources. In addition, Western is developing ways to identify and remove from further consultation those tasks that can be done with little or no effect to sensitive resources. A main goal of the environmental program is to reduce impacts to sensitive resources. This can be accomplished by avoiding resources, develop means of modifying the activity or the normal ways of doing maintenance, and by providing sensitivity training to craft and trade workers. Working with maintenance crews in the early planning stage is the key to reducing impacts. Understanding maintenance work is the key to getting their help.

*Keywords*: Transmission lines, maintenance, environmental impacts, sensitive resources, impacts, cultural resources, biological resources, minimizing impacts

## INTRODUCTION

The Western Area Power Administration (Western) is an agency of the U.S. Department of Energy. Western maintains four Regional Offices in Billings, Montana, Phoenix, Arizona, Loveland, Colorado, and Folsom, California. Western also has a customer service center for the Colorado River Storage Project in Salt Lake City, Utah, and a Corporate Service Office (CSO) in Golden, Colorado. Western markets the Federal government's portion of the electric power generated at 56 Federal hydroelectric dams and one coal-fired power plant to customers in 16 western states.

As an agency of the Federal government, Western is required to comply with a variety of environmental planning laws, regulations and Executive Orders for all of its actions. The laws and regulations include the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA), Native American Graves Protection and Repatriation Act (NAGPRA), American Indian Religious Freedom Act (AIRFA), the Migratory Bird Treaty Act (MBTA), Eagle Protection Act (EPA), and the Endangered Species Act (ESA). In addition, DOE has established procedures for implementing NEPA (10 CFR 1021) and the protection of floodplains and wetlands (10 CFR 1022). Western routinely operates and maintains more than 27,540 km (17,000 miles) of transmission lines and more than 250 major substations, along with meter-relay stations and communication facilities.

Maintenance of existing electrical transmission facilities results in environmental impacts. A common impression is that maintenance has no impacts because the construction of facilities has already been subject to environmental review. Many of Western's facilities were constructed before 1969, before NEPA or other environmental resource protection regulations were passed. The maintenance of transmission lines has changed, especially since many of our lines are now 50 years old, which means more intensive maintenance than for a line that is five years old. Finally, lines subjected to NEPA review may have maintenance impacts that go beyond the original environmental study or mitigation, and the impacts of maintenance may not have been a part of the original study.

## TYPES OF ROUTINE MAINTENANCE ACTIVITIES AND THEIR IMPACTS

Impacts of each of the general types of maintenance activities involve potential effects on sensitive cultural resources, protected plants, animals or habitats, important visual resources, and prime and unique farmlands. These may occur directly from the action, such as alteration of habitats, loss of individuals or disturbance such that understanding and/or scientific value is no longer available. Impacts may also be indirect; for example, transmission lines provide access to areas previously not open to humans.

Routine maintenance of transmission lines, using supporting structures of steel, concrete and wood, involve a variety of tasks, which will result in a variety of physical impacts. A listing of many of the job tasks is presented in Table 1. For illustration purposes, a few examples of environmental impacts are presented below.

Helicopter patrols may adversely affect big game species, primarily during parturition periods. They may also disturb migratory birds, such as raptors, nesting in the structures. Ground patrols may have the same impacts, but add the potential for ground-disturbing activities particularly if vehicles leave existing access roads or stray from the right-of-way.

Chemical vegetation control is mostly innocuous, if applicators follow herbicide labels, follow requirements regarding the avoidance of wetlands and riparian habitats, and ensure the herbicide does not leave the right-of-way. Mechanical control, especially when there are long periods between treatments, often involves ground disturbing activities, such as blading through dense stands of brush or pushing over larger trees. This can adversely affect biological resources through habitat alteration and direct mortality of species. Mechanical control can also affect surficial cultural resources (i.e., historic and prehistoric artifacts and features) which is obscured by heavy vegetation. If heavy equipment is used, it can also affect subsurface cultural resources.

Pole change-outs usually involve several maintenance vehicles, including truck-mounted augurs, cranes and bucket lift trucks, as well as heavy trucks to bring in new poles. The presence of this equipment and the necessary crew members can disturb wildlife species, particularly during sensitive periods in their annual life cycle. It also has the potential for disturbing both surface and subsurface cultural resources.

Replacing structure hardware, such as cross-arms, knee braces, or insulator bells typically requires several heavy duty trucks with equipment, a bucket truck, and crews to do the work. These activities occur at existing structures, using existing access roads. Because most of the work is performed overhead, impacts to the resources of concern are usually minimal. There is some potential for disturbing birds nesting on the structures. If the replacements are different from existing material, they may have visual impacts.

Access road work can include building new roads (because previous access is no longer allowed or available); improving existing roads by cut and fill operations (because of erosion or the need to bring in larger equipment than that for which the road was designed); or installing or replacing culverts, cattleguards, and gates. All these activities result in ground disturbance with the potential for visual, biological or cultural resource damage or destruction, varying degrees of habitat alteration, and the possibility of affecting prime and unique agricultural lands.

## ROUTINE COMPLIANCE ACTIVITIES

Federal and state resource management agencies usually have staff trained in the resource disciplines that the agencies are interested in protecting, such as landscape architects, archaeologists and ecologists. As an example, Western will contact agency archaeologists about cultural resource issues to identify sites that could be affected and for suggestions on which tribes should be contacted for consultation. The agency archaeologists will be interested in any maintenance activity that will disturb ground. Archaeologists and Tribal representatives may also be interested when Western proposes to move lines or facilities that are found in archaeologically sensitive areas.

Under the National Historic Preservation Act, Western is required to consult with the State Historic Preservation Officer (SHPO) on all activities that may impact properties that are eligible for the National Register of Historic Places. Western conducts surveys on all projects that have the potential to impact historic properties, then consults with the SHPO and any resource management agency on the likely impacts to those resources. Identification of sacred sites is done in consultation with the SHPO, tribes and other federal agencies. The sacred site issue can be a difficult one. Identifying these sites or placing boundaries on them is not easy. Usually, tribes are unwilling to make locations of sacred sites available. However, tribes now understand that they need to contribute to agency project planning efforts to protect sacred sites for their future use.

Besides consultation on individual actions, Western has initiated Programmatic Agreements (PAs) with the

**Table 1. Types of routine maintenance activities conducted by Western area**

**Line Maintenance**

Aerial Patrol

Wood and Steel Structures
- a. Framing
- b. Repair of broken or loose pole guards
- c. Pole top rescue and resuscitation
- d. Wood pole replacement under clearance and hot line orders
- e. Replacement of knee braces
- f. Replacement of crossarms
- g. X-brace installation on wood structures
- h. Assemble/disassemble
- i. Repair and replace steel on steel structures
- j. Installing dampeners
- k. Suspension insulators
- l. Set up of holan, condor, and Hi Ranger

Insulators
- a. Testing
- b. Replace broken or defective insulators

Aerial marker installation

Driving ground rods

Installation of anchors

Installation of armor rod and clipping-in structures

Removal and installation mile markers

Installation and removal of bird pans/bird guards

**Communications Facilities Maintenance**

Microwave towers and dish equipment
- a. Installation and removal
- b. Reflectors, ladder installation, safety cable for communications crew

Light beacon installation

**Substation Maintenance**

Installation of substation equipment (various)
- a. Transformers
- b. Regulators
- c. Capacitors
- d. Switches
- e. Wave Traps
- f. Bushings
- g. Radiators
- h. Breakers
- i. Lightning Arrestors
- j. Trenching
- k. Grounding Mats

Installing cut-out fuses

Adjust and clean disconnect switches and contacts

Switching

Transformer hook-ups

Silsbee test of transformers

**General Maintenance**

Concrete work (incidental)

Installing and repairing culverts

Installing and repairing fences

Installing and repairing footings

Constructing gates

Heavy Equipment driving, set up, and operating:
- a. Line truck
- b. Bucket truck
- c. Digger truck
- d. Dump truck
- e. Pole truck
- f. Stake bed truck
- g. Tanker truck
- h. Lowboy trailer
- i. Cranes
- j. Graders
- k. Bulldozer
- l. Front end loader
- m. Forklift
- n. Air compressor
- o. Jack hammer
- p. Generator
- q. Splint driver
- r. Backhoe
- s. Chipper
- t. Snowcat
- u. Tractor (farm)

Installing rip rap

Application of soil sterilants and herbicide

Tree trimming and felling, and brush clearing

Welding

Advisory Council on Historic Preservation and certain SHPOs that contain negotiated lists of maintenance activities. In these agreement documents, Western established classes of maintenance activities that: (1) have almost no potential to impact cultural resources and do not require consultation or archaeological surveys; (2) have a low-to-moderate potential for impacting cultural resources and are reviewed to decide the need to do record searches and/or surveys; and (3) have a high potential to impact cultural resources and will always be subjected to an on-the-ground survey.

Resource managers will also be consulted on biological issues. Included in this group are those managers responsible for the protection of endangered, threatened or sensitive species, critical or important habitats, and areas of concern or interest to the public. Resource managers represent not only state and Federal agencies, but also Tribes, environmental groups and the public. When it is determined that maintenance activities may affect endangered or threatened species or designated critical habitat, Western will enter formal consultation with the U.S. Fish and Wildlife Service.

Field surveys for sensitive resources are conducted routinely. These may include aerial surveys during routine line patrol for biological resources. Specific aerial surveys may be performed to address a specific activity or resource. For example, raptor nesting/roosting surveys are done before major activities at transmission structures. Pedestrian surveys are conducted to ensure that other resources are not impacted.

## MINIMIZING IMPACTS

When potential impacts to individual resources are identified, the landowner or resource-managing agency is contacted to learn their requirements for reducing impacts to resources. Plans for the mitigation, minimization or compensation of those impacts are then developed after consultation and depending upon landowner/manager constraints. Western will first attempt to avoid impacting resources. When that is not possible, Western can look to other ways of mitigation. This could include timing the activity to reduce impacts, reaching a consensus with other parties on reducing impacts, modifying the maintenance activities, modifying the equipment, or providing sensitivity training to maintenance staff to reduce the likelihood of adverse impacts.

Avoidance of the resource is the preferred means of reducing impacts. Avoidance can be achieved by denying or restricting access to the area. Some activities can be timed or access restricted during seasons when the resource is active or occupying the site. For example, most big game species have certain seasons when they need a certain type of habitat or undisturbed space, such as during reproductive activities. By timing maintenance activities to avoid those seasons, impacts are reduced.

When it appears Western cannot avoid a significant archaeological site, Western's environmental staff works closely with maintenance staff to find ways to reduce impacts. For example, where further archaeological work will be needed to reduce impacts (adverse effects), Western will complete a Memorandum of Agreement with the SHPO, land-managing agency and/or tribes that specify how impacts will be mitigated. In cases where the impacts will be minor (not adverse), Western has successfully used archaeological monitoring to limit impacts during the maintenance activity. Depending on the activity, the monitoring could be for identification of subsurface remains or for avoidance of significant surface features.

Access road closure, gate installation, use of different types of vehicles, and other modifications to normal maintenance procedures are often employed. For example, environmental staff will go to the field with

| TASK | SAFETY CONSIDERATIONS | | ENVIRONMENTAL CONSIDERATIONS | |
|---|---|---|---|---|
| | HAZARDS | TRAINING AND PREVENTION | ISSUES AND CONCERNS[1] | TRAINING AND PREVENTION |
| Heavy Equipment: Operation/ set up<br>a. Line truck<br>b. Bucket truck<br>c. Digger truck<br>d. Dump truck<br>e. Pole truck<br>f. Stake bed<br>g. Tanker<br>h. Lowboy<br>I. Cranes<br>j. Graders<br>k. Bulldozer<br>l. Front end Loader<br>m. Forklift<br>n. Air Compressor<br>o. Jack Hammer<br>p. Generator<br>q. Splint driver<br>r. Backhoe<br>s. Chipper<br>t. Snowcat<br>u. Tractor (farm) | 1. Personal injury<br>2. Electrical hazards<br>3. Unfamiliarity with different equipment<br>4. a. Backing<br>b. Passing<br>c. Braking distance<br>d. Fatigue<br>e. Truck condition<br>f. Oversize load<br>g. Hazardous material<br>h. High center of grayity and shifting loads | 1. Personal Protective Equipment (PPE)<br>2. a. Know clearances of different voltages<br>b. Blue stake where needed<br>c. Proper grounding of equipment<br>d. Tool box safety meeting & J.H.A.<br>3. a. Only qualified personnel should operate<br>b. Refresher classes with different equipment<br>4. a. Defensive driving<br>(1) Use of spotter<br>(2) Back slowly<br>(3) Walk around<br>(4) Back-up alarm<br>b. Keep safe distance<br>c. Defensive driving | A. Stay on Acess Road<br>B. Stay in right-of-way<br>C. Avoid ground disturbing activities<br>D. Avoid chemical or physical removal of vegetation<br>E. Impacts to nesting birds<br>F. Regulated materail issues | 1. Contact Regional environmental office |

Fig. 1. Sample page from Western's Job Hazard Analysis table for routine maintenance activities.

maintenance crews to understand how the maintenance project will be done. Discussions in the field frequently result in procedures to reduce impacts. In one case where maintenance needed to blade the access road through an archaeological site, fill was brought in to "plate" (cover to avoid disturbing) the most sensitive part of the site.

The use of rubber-tired vehicles in place of tracked vehicles has been employed to reduce impacts to wetlands in the northern Great Plains. Rubber-tired vehicles are also specified occasionally to reduce ground disturbance and impacts to cultural resources. However, in instances when the resources are so fragile, such as vernal pools in California, routine access is monitored. Perches and raptor nesting platforms have been added to structures to entice raptors away from the conductors and insulators where their presence would cause flash-overs and bird electrocutions.

To assist in the training of apprentice crafts and trades, Western developed a job analysis, which gave detailed descriptions of each action an electrician, meter-relay mechanic or lineman had to do to perform a job. The analysis was originally prepared as Safety training modules for the Craft Training Center that Western and several of its customers developed. Using this job analysis, the environmental staff from Western's Regional Offices and CSO developed a list of environmental concerns associated with each action for each job. An example is provided as Fig. 1. Using these job analyses, environmental awareness or sensitivity training for the crafts and trade personnel has been simplified. As shown in Fig. 1, when an activity may affect an environmental resource, the simple answer is to contact environmental staff. If the foreman or supervisor needs more information, it will be provided if it is not restricted due to the sensitivity of the resource. This is the case with some endangered plants and some cultural resources. Rather than tie up line crews with long sessions of environmental awareness training, environmental personnel will, if requested, sit in on the "tailgate sessions" in the morning before the crews go out. The only additional burden placed on maintenance crews is that environmental staffs be included in the long-range planning of maintenance activities.

## *BIOGRAPHICAL SKETCHES*

***John M. Bridges***

*Environmental Specialist, Western Area Power Administration, A3400, P.O. Box 3402, Golden, CO, 80401-0098, USA*

Fifteen years experience as a consultant to the energy industry, eight years experience with Western. Master of Science degree in Zoology, certified Wildlife Biologist in 1978.

***Mary Barger***

*Archaeologist/Federal Historic Preservation Officer, Western Area Power Administration, A3400, P.O. Box 3402, Golden, CO, 80401-0098, USA*

Twenty years with the Federal Government including the Department of Interior and Energy. Experience in midwest and western archaeology. Interest is in lithics and settlement patterns. BA from Western Illinois University and graduate studies at Western Michigan University.

***Nick Chevance***

*Environmental Specialist, Western Area Power Administration, A3400, P.O. Box 3402, Golden, CO, 80401-0098, USA*

Mr. Chevance holds a Masters degree from the University of Nebraska in Anthropology, and has worked for several Federal agencies, including the Forest Service, National Park Service, and the Bureau of Indian Affairs.

***Ted Anderson***

*Environmental Specialist, Western Area Power Administration (Upper Great Plains Region), B0401 BL, P.O. Box 35800, Billings, MT 59107-5800, USA*

***Rodney Jones***

*Environmental Specialist, Western Area Power Administration, J0420, P.O. Box 3700, Loveland, CO 80539-3003, USA*

***John Holt***

*Environmental Manager, Western Area Power Administration, G0400, P.O. Box 6457, Phoenix, AZ 85005-6457, USA*

***Earl Nelson***

*Environmental Specialist, Western Area Power Administration, N0411, 114 Parkshore Drive, Folsom, CA 95630-4710, USA*

# Edge Effects on Vegetation in Rights-of-Way

**Jacques Brisson, Alain Meilleur, Marie-Josée Fortin, and André Bouchard**

As a result of an increasing use of ecological methods for the control of vegetation in rights-of-way, it has become necessary to understand the natural processes that are likely to facilitate or hinder management objectives. Several factors may influence species composition within corridors, but edge effects of the vegetation immediately adjacent to the right-of-way is one of the most important. To better measure and understand edge effects, we studied the spatial distribution of vegetation types on test right-of-way sites located in southern Quebec. Sampling was done along 133 transects located perpendicular to the right-of-way, with a distance of 50 m between transects. Each transect consisted of seven quadrats covering the vegetation within the corridor and two quadrats outside of the corridor. The results show that there is a strong edge effect on plant composition in the right-of-way corridor, especially when it is bordered by a forest. The edge effects result in a greater dominance of tree species and to a lesser extent a greater number of shrubs. Besides species richness, the species composition is also different at the edge of the right-of-way, with several species more likely to be found at the edge, while others occur more often in the central zone. There was little significant difference between north-facing and south-facing edges. Seed dispersal is assumed to be the main factor responsible for edge effects on plant composition. These results have implications on vegetation management in right-of-way corridors.

*Keywords*: Edge effects, corridor, right-of-way, spatial analysis, vegetation management

## INTRODUCTION

One of the main objectives of vegetation management under powerline rights-of-way is to prevent or reduce the invasion or growth of trees. Environmental concerns brought an increasing use of ecological approaches to right-of-way management. It has become necessary to understand the natural processes that are likely to facilitate or hinder management objectives (Berkowitz, Canham, and Kelly 1995). Site conditions such as water regime or surficial material may be important factors in predicting tree invasion. For example, a humid depression supporting marsh plants such as cattail (*Typha latifolia*) will be less suitable to tree establishment, and thus will not require the same management as would a well-drained site of till deposit invaded by trembling aspen (*Populus tremuloides*). Yet, in a study of the vegetation of a powerline right-of-way in southern Quebec, we found that environmental variables such as drainage and soil conditions explained only 29% of the variance in vegetation based on a canonical correspondence analysis (Meilleur, Brisson, and Bouchard 1994). On right-of-way segments which are similar in abiotic conditions, some were strongly invaded by trees while others were dominated by shrub or herbaceous communities which are less suitable for tree invasion (Meilleur, Bouchard, and Bergeron 1994). From these observations, we hypothesized that the vegetation at the edge of rights-of-way may have a significant influence on its composition.

Edge effects can be defined as the changes in structure and composition of a community due to contact with another community type. Because of the linear nature of rights-of way, adjacent neighboring communities are always in close proximity, making edge effects potentially important. In the case of the edge effects of a forest on an open community type such as a right-of-way, the most direct influence of the forest is through the seed dispersal, which initiates tree invasion. However, the proximity of the forest may also influence the composition of the right-of-way by other means (Forman and Godron 1986). For example, the forest may act as a refuge for herbivores which come to feed in the neighboring right-of-way. Thus, pressure from herbivores may be greater in a right-of-way bordered by forests rather than by agricultural fields. In addition, the forest may act directly on the environmental conditions of the right-of-way, by reducing or funneling winds or by reducing solar radiation and temperature through shading. All of these effects may in turn influence the plant composition of rights-of-way. We must point out that despite the recent increase in scientific literature on edge effects, most of the articles focused on the effect of a non-forested site on a nearby forest edge, while few studied the opposite effects (Fraver 1994; Fritz and Merriam 1994; Matlack 1994).

The goal of our study is to measure the edge effects in a powerline right-of-way using methods of spatial analysis. We assume that the effects of bordering communities would be stronger at the edge of the right-of-way and decrease as we neared its center. We compare composition along transects perpendicular to the right-of-way in order to detect consistent differences in composition.

## METHODS

### Study site

The 60 m-wide right-of-way under study is for electrical powerlines. It is located in the south-western part of the province of Québec (Canada), between the Saint-Lawrence River to the north and the state of New York (U.S.A.) to the south (Fig. 1). The region has a humid continental climate. The annual average temperature is

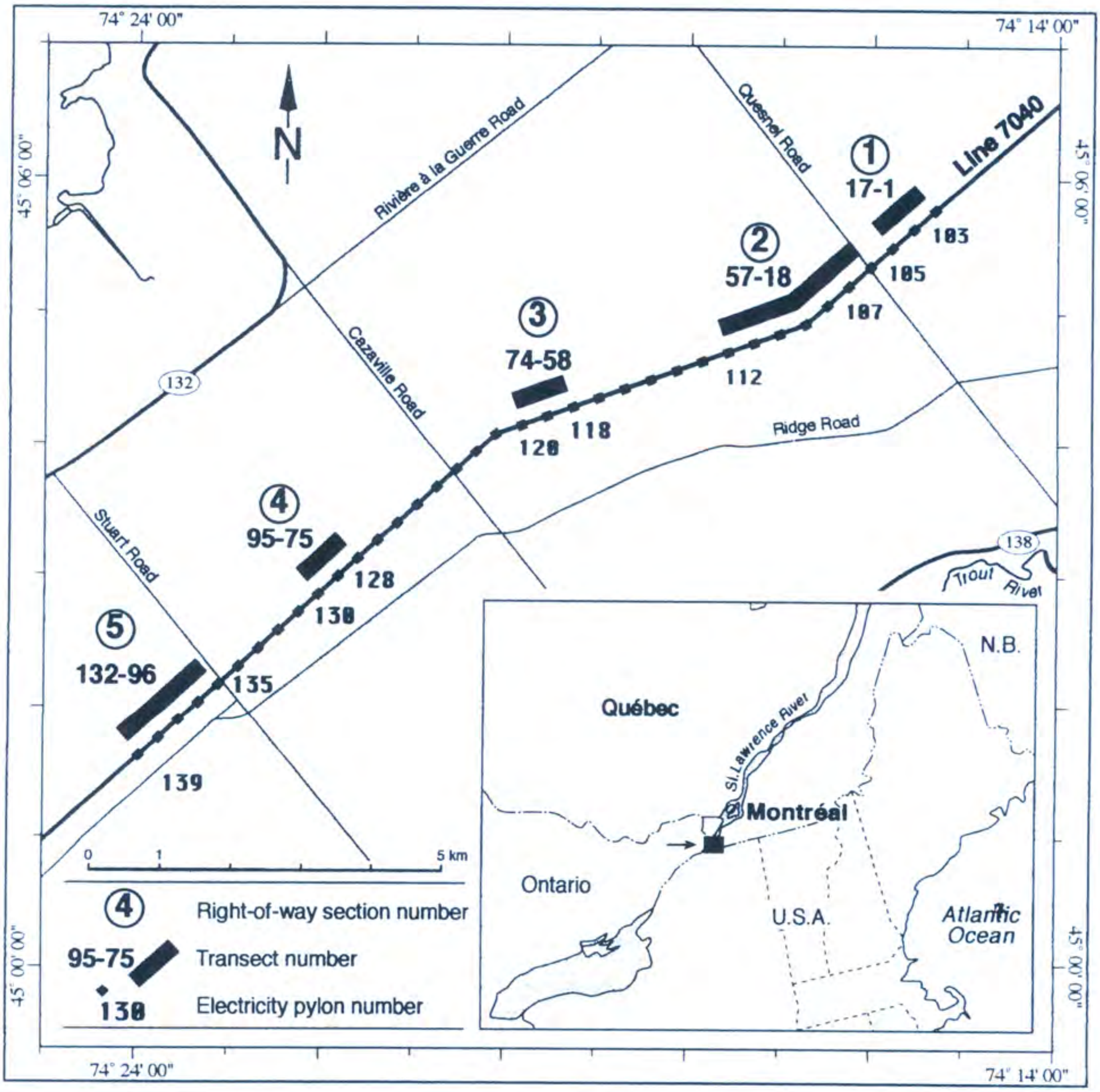



Fig. 1. Study area.

6.1°C in Huntingdon (elevation 75 m) with mean temperatures of –10°C in January and 20.8°C in July (Anonymous 1982). The average frost-free period is 140 days. The annual number of degree-days for plant growth is 2093 (Wilson 1971). The regional bedrock are dolomite and limestone (Globensky 1981).

The area under study is part of the northern hardwood zone that belongs to the Great Lakes–Saint-Lawrence Forest region (Rowe 1972). Mesic forests are generally dominated by *Acer saccharum*, with *Fagus grandifolia*, *Tsuga canadensis*, *Ostrya virginiana*, and *Tilia americana* (Meilleur, Bouchard, and Bergeron 1994). Forests growing on poorly drained soils or open sites are mostly dominated by *Fraxinus pennsylvanica* and *Acer rubrum*. *Acer saccharinum* can grow on more fertile and poorly drained sites, while on xeric sites *Pinus strobus*, *Acer rubrum*, *Populus tremuloides* and *Betula populifolia* are the dominant species (Meilleur, Bouchard, and Bergeron 1994).

The right-of-way, created in 1977, was previously occupied by 13% cultivated fields, 30% abandoned fields or shrubs, 35% aspen forests and 22% forests dominated by species such as *Acer saccharum*, *Thuya occidentalis* and *Pinus strobus*. Since the opening of the corridor, the vegetation mosaic has been modified by three herbicide treatments (foliar application of 2,4-D + picloram) in 1978, 1981 and 1984, as well as by manual cuts in 1987 and 1990.

## Sampling

During summer 1994, we sampled in five sections of a 32-km (20-mile) segment of the right-of-way (Fig. 1). These sections were selected in order to cover a wide range of community types bordering the right-of-way. Sections 1 and 2 are characterized by loamy soils and they are bordered by young disturbed forests and occasional agricultural fields. Section 3 is on well-drained moraine deposits and is mainly bordered by shrub communities and young forests. Section 4 is on sandy soil with imperfect drainage and is bordered by forests with different degrees of disturbance. Finally, Section 5 is characterized by organic surface deposits with poor drainage, and it is bordered by forests and occasional agricultural fields. A total of 133 transects were located perpendicular to the right-of-way, with a distance of 50 m between each transect within a right-of-way section. Each transect consisted of 7 quadrats of 5 × 5 m, equally spaced between both edges of the right-of-way corridor, with one quadrat right in the center (Fig. 2). Two additional circular quadrat of 15 m of radius were located in the adjacent communities on either side of the right-of-way. Their center was 20 m away from the nearest edge of the right-of-way (Fig. 2).

In each quadrat, we recorded microtopography and drainage. Percent plant cover was estimated for shrubs, trees and the most abundant herbaceous species. For less abundant herbaceous species or for more complex taxonomic groups, percent cover was estimated in categories: sedges, graminoids, rushes, other herbaceous species less that 30 cm high (low herbaceous), and other herbaceous species taller than 30 cm (high herbaceous). This method allowed us to efficiently increase sampling speed, and consequently sample size. In the forested quadrats, percent cover data for tree species were estimated for each of the following size-classes: (1) less than 5 cm in diameter at breast height (DBH), (2) DBH greater than 5 cm but less than 15 cm, and (3) DBH greater than 15 cm.

## Analysis

*Determination of discontinuities in right-of-way vegetation*
The goal of this analysis is to determine whether there are differences in vegetation from the edges of the right-of-way to its center by looking at discontinuities in composition. Two different algorithms were used to detect these discontinuities. Each analysis was performed on the entire data set as well as on data sets divided by growth form (herbaceous, shrubs, trees) and by right-of-way sections. While the lattice-wombling method finds discontinuities based on percent covers, the rate of change method is based entirely on presence–absence. The discontinuities found in each method may reflect different responses to underlying environmental processes (Fortin, Drapeau, and Jacquez 1996).

The lattice-wombling method computes the first partial derivative in the $x$ and $y$ spatial direction given the value of a variable (here species percent cover)

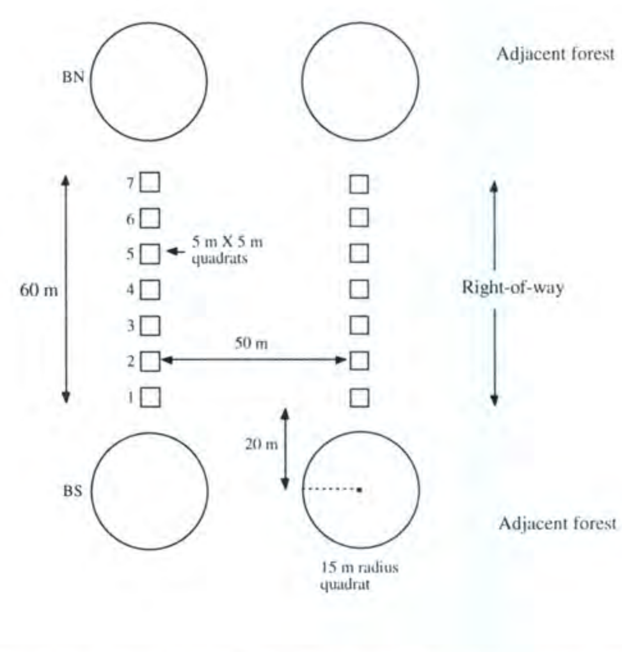



Fig. 2. Sampling design. BS = Quadrat in the plant community at the southern border of the right-of-way; BN = Quadrat in the plant community at the northern border of the right-of-way.

between sets of four sampled locations that form a square (for mathematical details and assumptions, see Fortin 1994, and Fortin and Drapeau 1995). The magnitude of rate of change in composition is calculated for the centroid location of each set of four samples. When the composition of the four corners is similar, the magnitude of the rate of change assigned to the centroid is close to zero, while it increases as the value at the four corners changes abruptly. Note that in our case, the set of four samples is defined as two neighboring quadrats of a transect, and their adjacent quadrats of the next parallel transect. The lattice-wombling method requires that rate of change be calculated on four points that are equidistant, which is not the case in our study. However, our results are valid since we consider rates of change in one direction only, perpendicular to the right-of-way. For multivariate data sets, the overall rate of change in composition is defined as the average rate of change of all the species' percent cover at a given centroid.

The second method looks at changes in composition based on species replacement along each transect analysed individually, using presence–absence data. In this method, a rate of change between two neighboring quadrat is simply calculated as the sum for all the species of the difference–mismatch between two adjacent sample locations along a transect (Oden, Sokal, Fortin, and Goebl 1993).

Both lattice-wombling and rate of change were calculated on observed data. To assess their statistical significance against the null hypothesis of absence of spatial pattern, 100 random permutations were generated (Fortin 1994).

*Relation between right-of-way vegetation and adjacent plant communities*

Several characteristics of the vegetation in the adjacent plant communities were determined from the species data: total number of species, number of species and relative frequency of herbaceous, shrubs and trees (total, <15 cm in DBH, >15 cm DBH). These characteristics were correlated with species diversity (total, herbaceous, shrubs, trees) of each quadrat of the same transect in the right-of-way, and rates of change of each quadrat pair as determined by the replacement method. Diversity was calculated as the average number of species per quadrat position (average richness). Correlations were performed separately for the northern and southern adjacent plant communities.

## RESULTS

In total, 102 species were sampled in the right-of-way and in the bordering communities, 71.6% of which were common to both territories. Of this total, 32 species were trees, 33 were shrubs and 37 were herbaceous. However, our number of herbaceous is an

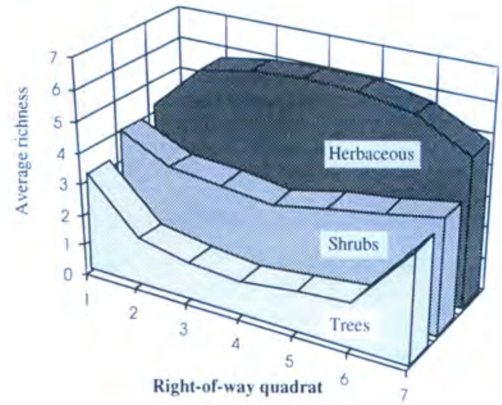



Fig. 3. Average richness of species of herbaceous, shrubs and trees according to position of right-of-way quadrats.

underestimation given the broad categories that we established in order to speed up sampling. The average number of species of trees and shrubs was maximum at the edge of the right-of-way and decreased toward the center (Fig. 3). The opposite pattern was observed for herbaceous species. The greatest change in average species richness occurred between the outer quadrat pairs (1–2 and 6–7).

Sharp discontinuities, as determined by the rate of change in species composition, also occurred mainly between outer quadrat pairs, especially for tree species (Table 1). There were no strong differences between northern and southern edges, except in the case of herbaceous species where there was a greater total number of discontinuities at the northern edge. However, this difference was not consistent across the entire right-of-way: it was entirely due to the contribution of Section 1, where there were seven significant discontinuities at the northern and none at the southern edge.

The pattern was slightly different when the Womble algorithm was used to determine sharp discontinuities in right-of-way vegetation. There were more significant discontinuities in the outer quadrat pairs than in central quadrats when tree species were considered, and to a lesser extent for shrub species, but the pattern was not as strong (Table 2). There was no clear pattern in the total number of discontinuities for herbaceous species. There were differences in patterns between right-of-way sections, with Section 5 showing 51 discontinuities as opposed to only seven significant discontinuities in Section 4. This difference may be only partly explained by the larger number of transects in Section 5 (37 transects compared to 21 for Section 4).

Most of the previous results suggest that the bordering community has the strongest effect at the edge of the right-of-way, and that the effect is especially strong on tree species. The characteristic of bordering plant communities that shows the strongest relationship to the right-of-way vegetation is the number of species represented in the tree layer (DBH > 15 cm), which is a composite indication of the successional stage of the

**Table 1. Number of significant discontinuities in species composition between neighboring quadrats located in the right-of-way, as calculated by the rate of change algorithm**

| ROW section | Growth form | Right-of-way quadrats boundary | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 |
| 1 | Herbaceous | – | – | – | 1 | 1 | 7 |
| | Shrubs | 1 | – | – | – | 3 | 1 |
| | Trees | – | – | – | – | – | 3 |
| 2 | Herbaceous | 1 | – | 1 | – | – | 1 |
| | Shrubs | 3 | 1 | 1 | – | – | 5 |
| | Trees | 8 | – | – | – | – | 2 |
| 3 | Herbaceous | 1 | – | – | – | – | 2 |
| | Shrubs | 1 | – | – | – | – | 1 |
| | Trees | – | – | – | – | – | 1 |
| 4 | Herbaceous | – | – | – | – | – | – |
| | Shrubs | 3 | – | – | – | – | – |
| | Trees | 1 | – | – | – | – | – |
| 5 | Herbaceous | 3 | 1 | 1 | 1 | 3 | 2 |
| | Shrubs | 4 | – | – | 1 | 3 | – |
| | Trees | 7 | 1 | – | – | – | 11 |
| Total | Herbaceous | 5 | 1 | 2 | 1 | 3 | 12 |
| | Shrubs | 12 | 1 | 1 | 1 | 3 | 7 |
| | Trees | 16 | 1 | – | – | – | 17 |

**Table 2. Number of significant discontinuities in species composition between neighboring quadrats located in the right-of-way, as calculated by Womble algorithm**

| ROW section | Growth form | Right-of-way quadrats boundary | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1–2 | 2–3 | 3–4 | 4–5 | 5–6 | 6–7 |
| 1 | Herbaceous | 3 | – | – | 1 | – | 1 |
| | Shrubs | 1 | – | – | – | – | 4 |
| | Trees | – | – | 1 | 1 | 1 | – |
| 2 | Herbaceous | 3 | 6 | 1 | 2 | 4 | – |
| | Shrubs | – | – | – | – | 1 | 1 |
| | Trees | 8 | – | – | – | – | 1 |
| 3 | Herbaceous | – | – | 1 | – | – | – |
| | Shrubs | – | – | – | – | – | 2 |
| | Trees | 8 | 6 | 5 | 5 | 11 | 13 |
| 4 | Herbaceous | – | – | – | – | – | – |
| | Shrubs | – | – | – | – | – | 3 |
| | Trees | – | – | – | – | 1 | 3 |
| 5 | Herbaceous | 1 | 2 | 1 | – | 1 | – |
| | Shrubs | 5 | 4 | 3 | 3 | 2 | 1 |
| | Trees | 4 | – | – | – | – | 7 |
| Total | Herbaceous | 7 | 8 | 3 | 3 | 5 | 1 |
| | Shrubs | 6 | 4 | 3 | 3 | 3 | 11 |
| | Trees | 20 | 6 | 6 | 6 | 13 | 24 |

**Table 3. Correlation between tree diversity (DHP > 15 cm) in the communities adjacent to the right-of-way (BS and BN) and the rate of change (herbaceous = H, Shrubs = S, and Trees = T) between the two nearest quadrats at the edge of the right-of-way. (+) = Positive correlation, (–) = Negative correlation, (*) Significance at $p = 0.05$, (**) Significance at $p = 0.01$, (***) Significance at $p = 0.01$.**

| ROW section | Correlation between tree diversity in bordering forest south (BS) and rate of change between the two nearest right-of-way quadrats (1–2) | | | | Correlation between tree diversity in bordering forest north (BN) and rate of change between the two nearest right-of-way quadrats (6–7) | | | |
|---|---|---|---|---|---|---|---|---|
| | H | S | T | HST | H | S | T | HST |
| 1 | – | +* | +* | +* | + | – | +* | + |
| 2 | –* | – | + | – | – | – | + | – |
| 3 | – | – | + | – | + | – | + | + |
| 4 | + | + | +* | + | – | –* | – | – |
| 5 | – | + | + | + | – | + | + | + |
| Total | – | + | +*** | + | – | – | + | – |

vegetation (abandoned fields and young communities have a value of 0) and of the diversity of the forest.The most significant correlation was between this measure and tree species diversity in the nearest right-of-way quadrat, both for the south and the north edges (Table 3). This relationship may extend to the third nearest quadrat although the positive correlation was not significant. There was a negative correlation between tree diversity in the northern bordering forest and shrub diversity in all right-of-way quadrats, while the relationship with the southern forest was positive for the nearest quadrat and varied thereafter. There was also an apparent difference in the relation between herbaceous species diversity in the right-of-way and the aspect, with an overall positive correlation for the southern forest edge and a negative one for the northern forest edge. However, few of these correlations were significant.

**Table 4. Correlation between tree diversity (DHP > 15 cm) in the communities adjacent to the right-of-way (BS and BN) and species diversity (herbaceous, shrubs and trees) in the right-of-way according to quadrat position. Note that the order of the quadrats reflects a decreasing distance from the edge: for BS from quadrat 1 to 7, for BN from quadrat 7 to 1.**

| | Right-of-way quadrats relative to their position from the bordering forest | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| Herbaceous – BS | + | + | +* | + | + | – | + |
| Herbaceous – BN | – | – | – | – | – | – | – |
| Shrubs – BS | +* | + | –* | – | –* | – | + |
| Shrubs – BN | –* | –** | –* | –* | –* | –** | –* |
| Trees – BS | +*** | + | + | + | – | – | + |
| Trees – BN | +*** | + | + | – | + | + | + |

1st = nearest; 7th = furthest.

Tree diversity in the bordering communities also best explained the high discontinuities in tree species diversity between neighboring quadrats at the edge of the right-of-way. In all the sections, there were positive correlations (three of which were statistically significant) between bordering forest diversity and the rate of change of the two nearest quadrats, with the exception of the northern border of Section 4 (Table 4). The overall relationship was highly significant for the southern border. There were no clear patterns for discontinuities in terms of shrub or herbaceous diversity.

Of the 25 tree species that occurred in all right-of-way sections, 19 were more likely to be found at the edge (Table 5). This included all four tree species that are considered shade tolerant, i.e. *Acer saccharum, Fagus grandifolia, Ostrya virginiana,* and *Tilia americana*. There was also a large number of shrub species that were more abundant at the edge, some of which are characteristic of the forest understory such as *Acer spicatum, Cornus alternifolia* and *Taxus canadensis*. There was only one herbaceous species, *Apocynum androsaemifolium*, that was significantly more likely to occur at the edge of the right-of-way. Of the 38 species showing preference to right-of-way edges, only two were significantly more likely to be found at one edge in particular: both *Quercus macrocarpa* and *Vitis riparia* preferred the northern edge (Table 5).

The picture was very different in the central zone of the right-of-way, where no trees and only two species of shrubs were more likely to be found (Table 6). In contrast, there were 11 species or categories of herbaceous more likely to be found in the central zone. If we exclude the "high herbaceous species" and "low herbaceous species" categories, about which no conclusion can be drawn, all of the others were species or genera characteristic of open communities.

**Table 5. Species significantly more likely to be found at the edge of the right-of-way ($\chi^2$ test with $p < 0.05$). (N) = More likely to be found at the northern edge**


| Species | Growth form* | | | Shade tolerance* | | |
|---|---|---|---|---|---|---|
| | H | S | T | I | M | T |
| *Acer rubrum* | | | x | | x | |
| *Acer saccharinum* | | | x | | x | |
| *Acer saccharum* | | | x | | | x |
| *Acer spicatum* | | x | | | | x |
| *Alnus rugosa* | | x | | | x | |
| *Amelanchier* sp. | | x | | x | | |
| *Apocynum androsaemifolium* | x | | | x | | |
| *Betula alleghaniensis* | | | x | | x | |
| *Betula populifolia* | | | x | x | | |
| *Carpinus caroliniana* | | x | | x | | |
| *Carya cordiformis* | | | x | | x | |
| *Celastrus scandens* | | x | | | x | |
| *Cornus alternifolia* | | x | | x | | |
| *Cornus stolonifera* | | x | | x | | |
| *Fagus grandifolia* | | | x | | | x |
| *Fraxinus pensylvanica* | | | x | | x | |
| *Ilex verticillata* | | x | | x | | |
| *Malus pumila* | | x | | x | | |
| *Ostrya virginiana* | | | x | | | x |
| *Parthenocissus quinquefolia* | | x | | | x | |
| *Pinus strobus* | | | x | | x | |
| *Populus balsamifera* | | | x | x | | |
| *Populus grandidentata* | | | x | x | | |
| *Populus tremuloides* | | | x | x | | |
| *Prunus pensylvanica* | | | x | x | | |
| *Prunus serotina* | | | x | | x | |
| *Prunus virginiana* | | x | | x | | |
| *Quercus macrocarpa* (N) | | | x | | x | |
| *Rhamnus catharticus* | | x | | x | | |
| *Ribes* sp. | | x | | | x | |
| *Rubus odoratus* | | x | | x | | |
| *Taxus canadensis* | | x | | | | x |
| *Thuya occidentalis* | | | x | | x | |
| *Tilia americana* | | | x | | | x |
| *Ulmus americana* | | | x | | x | |
| *Viburnum lentago* | | x | | x | | |
| *Vitis riparia* (N) | | x | | | x | |
| *Zanthoxylum americanum* | | x | | x | | |
| Total | 1 | 18 | 19 | 16 | 16 | 6 |

*Growth form: H = herbaceous, S = shrubs, T = trees.
Shade tolerance: I = intolerant, M = intermediate, T = tolerant.

**Table 6. Species significantly less likely to be found at the edge of the right-of-way ($\chi^2$ test with $p < 0.05$).**


| Species or categories | Growth form | | |
|---|---|---|---|
| | H | S | T |
| *Asclepias syriaca* | x | | |
| *Daucus carota* | x | | |
| *Eupatorium perfoliatum* | x | | |
| *Graminaceous* | x | | |
| Low herbaceous species | x | | |
| High herbaceous species | x | | |
| *Hypericum perforatum* | x | | |
| *Lytrum salicaria* | x | | |
| *Pastinaca sativa* | x | | |
| *Phragmites communis* | x | | |
| *Rubus occidentalis* | | x | |
| *Salix petiolaris* | | x | |
| *Scirpus* sp. | x | | |
| Total | 10 | 2 | 0 |

## DISCUSSION

### Edge effects

There is a strong edge effect on plant composition in the right-of-way corridor. This effect manifests itself especially at the very border of the right-of-way. When the community that borders the right-of-way is a forest with high tree diversity, the edge effect results in a greater dominance of tree species and, to a lesser extent, a greater number of shrubs. Besides species richness, the species composition is also different at the edge of the right-of-way, with several species more likely to be found at the edge, while others are more likely to occur in the central zone. The edge effect does not seem to extend very far from the edge, since beyond a certain distance from it, the vegetation becomes more uniform.

It seems obvious that the proximity of seed bearing trees probably explains the pattern observed for tree species to a large degree, since seed dispersal is often cited as an important limiting factor in right-of-way corridors (Hill, Canham, and Wood 1995). Changes in the environment at the edge of the right-of-way may also be favorable to some species. For example, the southern edge experiences prolonged periods of shade when it is bordered by a forest, a factor that should provide an advantage to species of intermediate to high shade tolerance. However, the low difference in species composition between the northern and southern edges of the right-of-way suggests that this factor does not play a major role in our case.

In the recent literature, the significance of the edge effects has been primarily studied in reference to the effects of abutting pastures or clearcuts on forest edges. It was found that these forest edges typically had increased solar radiation (Kapos 1989; Brothers and Spingharn 1992), lower humidity and higher air temperature (Kapos 1989; Williams-Linera 1990), higher soil temperature (Brothers and Spingharn 1992) and increased wind speed (Raynor 1971). These changes, in turn, alter plant species composition and structure. Forest edges generally have higher stem density than the forest interior (Wales 1972; Whitney and Runkle 1981; Ranney et al. 1981), a greater proportion of shade intolerant species and exotic plant species (Whitney and Runkle 1981; Ranney, Bruner, and Levenson 1981), and a greater species richness (Brothers and Spingharn 1992). There were also differences between the north-facing edges as opposed to south-facing edges, with the edge effect generally strongest on south-facing edges, presumably due to increased solar radiation (Wales 1972; Palik and Murphy 1990). While several studies showed results that were not always consistent with these generalizations (Matlack 1994; Murcia 1995), edge effects on forest ecosystems were often found to be an important factor in affecting plant composition and structure.

The edge effect of abutting forest on open plant communities such as abandoned fields or rights-of-way is also an important structuring factor, but one that has attracted much less interest in the scientific literature. While the edge effect on forests is assumed to be mainly due to changes in the physical environment, the edge effect on open communities may be largely a result of a difference in propagule availability. Changes in solar radiation, humidity and temperature may also play an important role, and one that should be different between north-facing and south-facing edges, although our results do not reveal any such significant differences.

In the right-of-way corridor we studied, the establishment of shade tolerant, forest interior species was almost entirely due to edge effects. Most other tree species were also more frequently present at the edge. The lesser abundance and diversity of herbaceous species at the edge is probably the result of competitive exclusion by shading from woody species. As a result, edges are more rapidly dominated by woody species, which eventually reach a development that is incompatible with power-line operation and safety.

### Management recommendations

The objective of vegetation management on powerline rights-of-way is to reduce woody plant populations that may interfere with powerline operation. The proximity of a forest enhances the invasion and dominance of tree species at the right-of-way edge, thus increasing the frequency of required interventions and the cost of vegetation management. Therefore, it is recommended that when new corridors are planned in a patchy landscape, forest patches should be avoided when possible (Luken 1991). For existing rights-of-way, since the edge effect is particularly strong at the very edge of the corridor, the possibility of enlarging the corridor when it is bordered by a forest should be examined and weighed against other costs. The zone of significant tree invasion would then be located outside the original zone acceptable for powerline operation and safety, thus reducing intervention frequency. Finally, alternative ecological methods for reducing tree invasion, such as the establishment of dense shrub or herbaceous communities that inhibit tree establishment (Meilleur, Véronneau, and Bouchard 1997) should be implemented preferentially at the edge of right-of-way corridors bordered by forests, in order to maximize their benefits.

## ACKNOWLEDGMENTS

This research was carried out under contract with Hydro-Québec (grant ENVC-91-ADHOC-00-022) with additional support from the government of Canada (Federal Summer Employment Program). We are particularly grateful to Ms. Louise Jodoin for data analysis, and to Ms. Catherine Boudreault, Ms. Sylvie de Blois and Mr. Jean-François Fortin for their assistance with the field work. Ms. Patricia Wood helped with the translation of the manuscript, and Ms. Roxanne Desjardins helped with the figures.

## REFERENCES

Anonymous. 1982. Normales climatiques du Canada 1951–1980. Températures et précipitations-Québec. Service de l'environnement atmosphérique. Environnement Canada, 216 pp.

Berkowitz, A.R., C.D. Canham, and V.R. Kelly. 1995. Competition vs. facilitation of tree seedling growth and survival in early successional communities. Ecology, 76: 1156–1168.

Brothers, T.S. and A. Spingarn. 1992. Forest fragmentation and alien plant invasion of central Indiana old-growth forests. Conservation Biology, 6: 91–200.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. John Wiley & Sons, New York. 619 pp.

Fortin, M.-J. 1994. Edge detection algorithms for two-dimensional ecological data. Ecology, 75: 956–965.

Fortin, M.-J. and P. Drapeau. 1995. Delineation of ecological boundaries: comparison of approaches and significance tests. Oikos, 72: 323–332.

Fortin, M.-J., P. Drapeau, and G.M. Jacquez. 1996. Quantification of the spatial co-occurrences of ecological boundaries. Oikos, 77: 1–10.

Fraver, S. 1994. Vegetation responses along edge-to-interior gradients in the mixed hardwood forests of the Roanoke River Basin, North Carolina. Conservation Biology, 8: 822–832.

Fritz, R. and G. Merriam. 1994. Fencerow and forest edge vegetation structure in eastern Ontario farmland. Ecoscience, 1: 160–172.

Globenski, Y. 1981. Région de Huntingdon. Rapport géologique 198, Ministère Énergie et Ressources, Gouvernement du Québec, 53 pp.

Hill, J.D., C.D. Canham, and D.M. Wood. 1995. Patterns and causes of resistance to tree invasion in rights-of-way. Ecological Applications, 5: 459–470.

Kapos, V. 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. Journal of Tropical Ecology, 5: 173–185.

Luken, J.O. 1991. Managing power-line corridor vegetation. Journal of Arboriculture, 17: 318–321.

Matlack, G.R. 1994. Vegetation dynamics of the forest edge — trends in space and successional time. Journal of Ecology, 82: 113–123.

Meilleur, A., A. Bouchard, and Y. Bergeron. 1994. The relation between geomorphology and forest community types of the Haut-Saint-Laurent, Quebec. Vegetatio, 111: 173–192.

Meilleur, A., J. Brisson, and A. Bouchard. 1994. La maîtrise biologique de la végétation incompatible sous les lignes de transport d'électricité d'Hydro-Québec. Phase IV: Mise en application. Report presented to the vice-presidence of Environnement, Hydro-Québec. Institut de recherche en biologie végétale, Université de Montréal. 97 pp.

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

Meilleur, A., H. Véronneau, and A. Bouchard. 1997. Shrub propagation techniques for biological control of invading tree species. Environmental Management, 21: 433–442.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution, 10: 58–62.

Oden, N.L., R.R. Sokal, M.-J. Fortin, and H. Goebl. 1993. Categorical wombling: determining regions of abrupt change in categorical variables. Geographical Analysis, 25: 315–336.

Palik, B.J. and P.G. Murphy. 1990. Disturbance versus edge effects in sugar-maple/beech forest fragments. Forest Ecology and Management, 32: 187–202.

Ranney, J.W., M.C. Bruner, and J.B. Levenson. 1981. The importance of edge in the structure and dynamics of forest islands. In: Forest island dynamics in a man-dominated landscape. R.L. Burgess and D.M. Sharp, eds. Springer-Verlag, New York. pp. 67–95.

Raynor, G.S. 1971. Wind and temperature structure in a coniferous forest and a contiguous field. Forest Science, 17: 351–363.

Rowe, J.S. 1972. Les régions forestières du Canada. Ministère de l'Environnement, Service canadien des forêts. Information Canada, Publication 1300F, 172 pp.

Wales, B. 1972. Vegetation analysis of north and south edges in a mature oak-hickory forest. Ecological Monographs, 42: 451–471.

Whitney, G.G. and J.R. Runkle. 1981. Edge versus age effects in the development of a beech-maple forest. Oikos, 37: 377–381.

Williams-Linera, G. 1990. Vegetation structure and environmental conditions of forest edges in Panama. Journal of Ecology, 78: 356373.

Wilson, C.V. 1971. Le climat du Québec. Atlas climatologique, 1re partie. Études climatologiques. Service météorologique du Canada.

## *BIOGRAPHICAL SKETCHES*

***Jacques Brisson***

*Institut de Recherche en Biologie Végétale, (Université de Montréal), 4101 Sherbrooke St. East, Montréal, Québec, Canada, H1X 2B2*

Dr. Jacques Brisson (M.Sc. Univ. de Montréal; Ph.D. UC Davis/SDSU) is a researcher at the Montreal Botanical Garden and at the Institut de Recherche en Biologie Végétale. His research centers mainly on plant competition and forest dynamics. Current research projects include vegetation analysis and management within Hydro-Québec rights-of-way.

***Alain Meilleur***

*Institut de Recherche en Biologie Végétale, (Université de Montréal), 4101 Sherbrooke St. East, Montréal, Québec, Canada, H1X 2B2*

Dr. Alain Meilleur (M.Sc. Univ. de Montréal; Ph.D. Univ. de Montréal) is an assistant researcher at the Institut de Recherche en Biologie Végétale. His main research focuses on biological control by shrub species in rights-of-way which include experimental treatments, stem and root architectures, and vegetative propagation studies. Other research areas include plant ecology, fire ecology and ecological classification.

***Marie-Josée Fortin***

*Département de Biologie, Université de Sherbrooke, Sherbrooke, Québec, Canada, J1K 2R1*

Dr. Marie-Josée Fortin (M.Sc. Univ. de Montréal; Ph.D. SUNY at Stony Brook) is an assistant professor at the Geography Department of the Université de Montréal. Her research focuses on assessing the relationships between forest spatial dynamics and natural as well as human disturbances. Other research area include landscape ecology, fire ecology, ecotone dynamics, biodiversity, spatial analysis, sampling design and ecological studies.

***André Bouchard***

*Institut de Recherche en Biologie Végétale, (Université de Montréal), 4101 Sherbrooke St. East, Montréal, Québec, Canada, H1X 2B2*

Dr. André Bouchard (M.Sc. McGill; Ph.D. Cornell) is a professor of ecology at the Biology Department of the Université de Montréal. From 1975 to 1996, he was curator of the Montreal Botanical Garden. His research has centered on rare plants, vegetation and landuse planning in Newfoundland and in southern Québec. His current research projects focus on vegetation analysis and management within Hydro-Québec rights-of-way and landscape changes in southern Québec during the 19th and 20th centuries.

# Study of the Iberian Flora Compatible with Power Lines

**Javier Arévalo-Camacho, Jorge Roig-Solés, Carlos Morla Juaristi, Fernando Gómez Manzaneque, Elena Bermejo Bermejo, Felipe Domínguez Lozano, Jesús Maza Pecino, Susana Molinero Herranz, and Leoncio Moreno Rivero**

This study analyzes the main characteristics of a large number (450) of the most representative woodland species from both wet and dry regions in Europe and their relationship with high voltage overhead power lines, including all trees and most bushes and shrubs that form significant woodland communities on the Iberian peninsula. Once the initial species list had been compiled, the next step was to analyze the specific characteristics of each specie to assess its compatibility with overhead power lines, and create a database for easy selection of the most suitable species for each ecosystem. This compatibility is represented by an index obtained by first analyzing both morphological and ecological characteristics of all species included in this catalogue, and then to identify those most suitable for the power line rights-of-way (ROW). These characteristics are: limited growth, poor combustion (low burning capacity or a tendency to retard the spreading of a fire), the covering of a large area to crowd out competition, soft stems for easy passage through the ROW and finally, a preference for light soil to prevent the invasion of existing pathways.

*Keywords*: Vegetation, forest management, right-of-way, ROW, powerlines, protection measures

## BACKGROUND

Rights-of-way (ROWs) are one of the characteristic features of overhead power lines and are largely responsible for the environmental impact attributed to them. This is due to the fact that the opening up and upkeep of the rights-of-way (ROWs) implies a direct impact, significant in certain zones, on plant life and scenery, and an indirect impact on other environmental elements.

Red Eléctrica de España, the company responsible for running the Spanish National Electrical Grid, has developed a series of preventative and corrective measures designed to reduce or minimize the environmental impact of the opening and/or upkeep of the ROWs.

These measures concentrate on the reduction of the area to be cut or on the regeneration of affected areas, always in accordance with legal precepts and the necessary technical conditions for the correct maintenance and safety of the network and their surroundings. The corrective measures taken in new lines are based on the determination of the route to be followed and the construction methods used, as well as considering the composition and characteristics of the woodland to be crossed.

With existing lines, however, this last aspect is the only one that can be acted upon. In this case maintenance measures are taken to reduce the impact on plant life of the opening and upkeep of the ROWs, based on the following actions: the maintenance of the existing plant formation, resorting to ROWs of variable width; selective cutting, allowing the preservation of any protected species present; or the replanting of degraded areas with species compatible with the lines.

In many cases such measures cannot readily be taken due to a lack of knowledge about the species present, including whether or not they are protected and, in particular, the presence of species considered as suitable for co-existing with the line.

To solve this problem, the Environmental Service of Red Eléctrica, in collaboration with the Unidad Botánica del Departamento de Silvopascicultura de la Escuela Técnica Superior de Ingenieros de Montes (Botanical Unit of the Department of the Higher Technical School of Forest Engineering), has designed a project aimed at rationalizing the co-existence between power lines and plant life. This goal can be accomplished by increasing the knowledge of the behavior of the plant species forming the woodland community crossed by the lines and their degree of compatibility with power lines, and by setting up a tool allowing optimum long-term management of the woodland formations (trees and shrubs) affected by the ROWs.

## AIM OF THE CATALOGUE

In a country like Spain it is particularly difficult to draw up a list of species compatible with the power lines, due to the richness and variety of the ecosystems found there. This means that very different species are present in various parts of the Iberian peninsula, and that the same species might grow to a considerable height in one area while it grows only to bush height in another area.

The objective of this work was therefore to analyze the most common woodland species by means of a detailed examination of the Iberian vascular flora to arrive at a catalogue of the species compatible with the lines in different bio-climatic zones. This would result in a list of those species that could be used to reduce the impact of the ROWs, either by maintaining these desirable species in the ROWs or by establishing them to form a stable plant cover. Plants could be established by direct planting or allow nearby succession to occur.

The first step in drawing up this catalogue was determining the characteristics that the plant species must have to be considered as compatible with the lines, such as having a reduced maximum height, low flammability, etc., as well as taking into account the different environmental characteristics in the various zones of the Iberian peninsula. Once these characteristics were established, the next step was the to study an appreciable number of species to identify those whose presence in the ROWs could be considered as compatible with the existing line, giving each species catalogued a compatibility index.

A selection of 450 Iberian flora species was used in compiling the catalogue, including all woody species belonging to the higher field layers (trees, shrubs and scrub). Most species selected for the analysis (400) are native to Spain, but a series of non-native or introduced species has also been included (about 50) due to the importance they have attained in Spanish plant life, such as the eucalyptus tree.

The catalogue includes an appreciable part of the woody plants of Europe, in particular almost all of the higher level species of the Mediterranean area. Data obtained may well be extrapolated to countries bordering the Mediterranean Sea, and as far as the species of Atlantic-type woodland plant communities are concerned, to the rest of Europe.

Once the compatible plant species catalogue was drawn up, a database was created including all the catalogue species and their characteristics. A program for management of the database was also created, based on comparative criteria and a polynomial to indicate which species would be suitable for each line based on the characteristics of the zone crossed.

## JUSTIFICATION FOR THE OPENING UP OF ROWS

In order to function correctly, power lines have to be kept isolated to assure uninterrupted supply and distribution of the power and also to avoid damage to elements that might come into contact with the lines. A safe distance must be maintained between the power lines and nearby objects in contact with the ground, if not the current from the power lines would be grounded through the object.

Regulations on power lines therefore establish minimum safety distances between the lines and all objects, uses and services crossed. Safe distance must be kept between power lines and buildings, rivers, roads, railways, other power lines, wooded areas, etc. In the case of a line that passes through a wooded area, the maintenance of a leeway between the line and trees is necessary both for the continuity of the power supply and for the safety of the woodland itself, since any grounding through a tree, besides cutting off the power supply, would involve the added risk of starting a forest fire.

Because of safety regulations, electricity utilities open up ROWs, usually of a permanent width, where power lines cross wooded areas (Fig. 1), although, none of the aforementioned regulations stipulate, expressly or tacitly, the opening up a ROW free of all trees. The line regulations stipulate only a safety distance depending on the voltage involved, and the fire regulations state that a ROW free of "dry vegetation" has to be maintained. Therefore, although in certain cases it is necessary to open up a ROW, there will be many other areas where this measure is by no means so essential.

Another very important aspect to be bear in mind in the design of the ROWs is that, besides safeguarding the woodland, they also have a beneficial effect for the line itself in the event of a forest fire. ROWs stop the fire from spreading to the area immediately below or very close to the line, where it might cause such direct damage as distortion of pylons and/or cables or a pollution of the insulators, which would reduce their insulation capacity, etc. All these effects would be serious and would lead to at least a temporary power supply failure.

Even where there is no danger of the aforementioned damage, because of the distance between fire and line, a forest fire could still lead to supply cut-offs due to the potential grounding of the line through the fire's smoke. This circumstance is used to justify the opening up of ROWs in scrubby areas, where the risk of direct damage by the flames is practically nonexistent.

One of the justifications used for keeping the ROW free of trees and shrubs is that it often functions as a

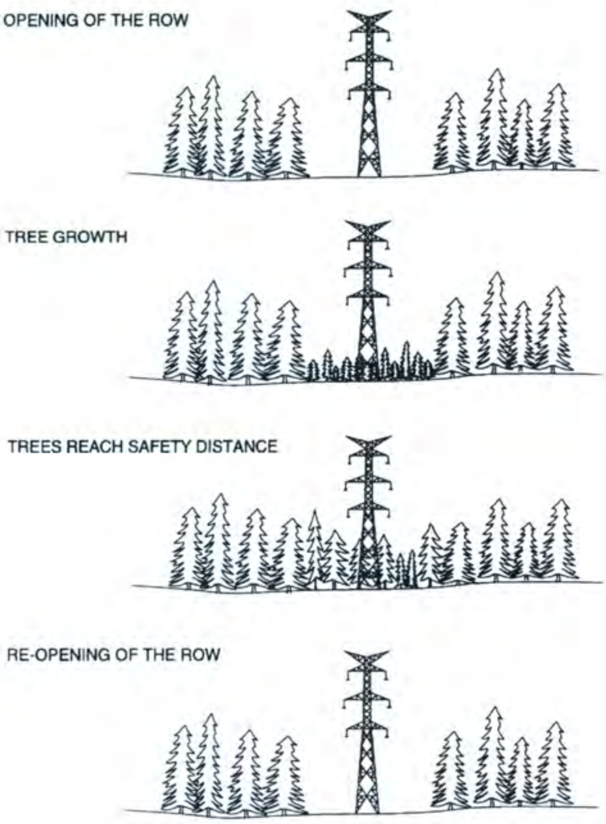



Fig. 1. Time cycle in the actual treatment of right-of-way.

firebreak. This could have a very positive effect on woodland management, and indeed it is often woodland areas managers who themselves recommend or demand the existence of firebreaks.

It should also be pointed out, however, that in many cases the line does not follow the ideal path for a firebreak and may even rouse the opposite effect, so their use as firebreaks can by no means be extrapolated to all situations.

All these factors taken together point to a ROW of increasing width according to the risk involved. In terms of safety the width would be minimal, since it would only be necessary a short distance between cables and vegetation throughout a reasonable time and greater then considering the effects of a possible nearby fire.

The ROW, however, is not kept clear of vegetation forever, since the cleared ground usually becomes covered by trees and shrubs, especially in certain types of scrubby formations. In a few years, the ROW ceases to serve as a firebreak. This period will be shorter, as regeneration capacity of the plant communities involved is greater. It may therefore be the case, especially in scrubby areas (gorse heaths or cistus beds, etc.), that a ROW grows over again in only two or three years of being opened up, and therefore the process has to be repeated.

It follows from the above that the ROW has to be periodically re-opened, implying a permanent cost for the owner of the lines (Fig. 1). This periodical work also implies an environmental cost, since the opening up and upkeep of the ROW involves an impact on the surrounding environment in general and on the plant life in particular.

## ROW SIZE

A factor to be considered when calculating the ROW size is the distance between cables and tree branches, which depends, upon other factors, on the distance between the cables and the ground.

In general, it can be said that the distance of the cables from the ground varies throughout the span between pylons; on flat ground it is maximum at the pylon and minimum in the middle of the span, although this depends on the lay of the land. The minimum distance depends on the voltage.

In 400 kV lines, such as those of Red Eléctrica, the lowest height of the cables varies, in flat ground without vegetation, between 20 m at the pylon and a minimum of 8 m in the middle of the span.

It should also be considered that the distance between the cables and the ground varies according to the time of year and the power carried, which produces variations in the temperature of the cables, causing them to stretch or shrink and changing the distance between the cables and the ground. Since usually the cables are lower in summer than in winter, the risk of fire is greater at that time of the year.

Another technical conditioning is the sideways movement of the cables because of the wind. A line project has to include in its calculations the effect on the cables of a cross wind of 120 km/h, which will be greater in the center of the span. Therefore, the calculation of the ROW width has to take into account not only the trees below the line but also those situated on both sides, and this sideways movement to observe the predetermined safety criteria (Fig. 2).

The other basic factor when designing the ROWs is the characteristics of the plant life present, especially the tree species and the actual and future growth of the particular examples in the zone. The natural growth of trees implies that the distance between them and the cables gradually decreases, and the safety distance could eventually be trespassed.

This growth is very variable since it depends not only on the species involved and their particular morphology, though this is the main factor to be considered, but also on other factors such as the specific characteristics of the area. Species that grow quite high in some areas do not get beyond bush height in others, since climatic and soil conditions affect the height and appearance of the species present. This is the reason for the great variety of phytoclimatic regions in Spain.

The difficulty of taking all these variable factors into account meant that until recently a ROW of permanent

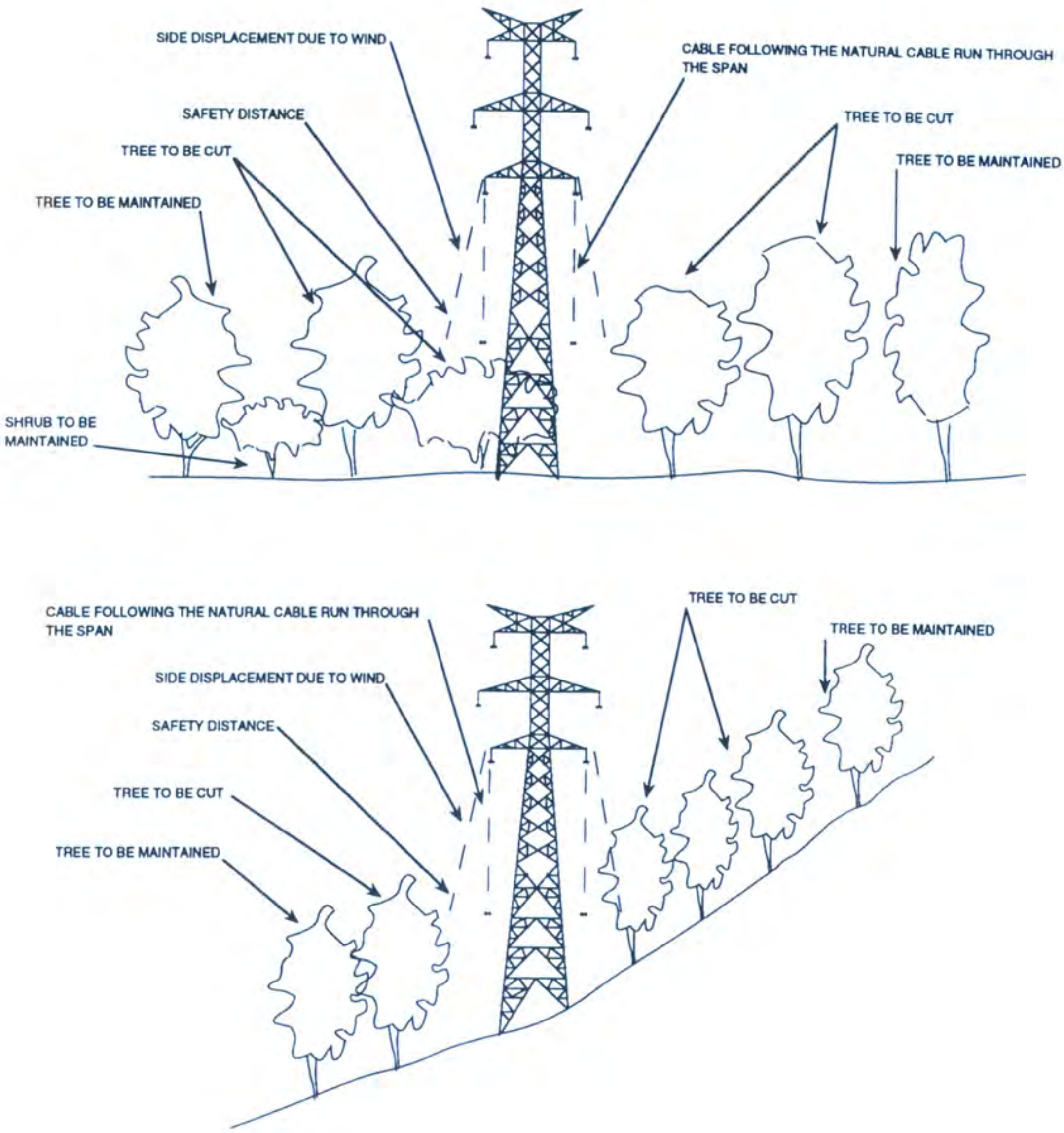



Fig. 2. Definition of ROW, according to the Spanish power lines regulation.

width was maintained under the lines. For 400 kV lines this width normally ranged from 30 to 40 m, and was increased up to 60 m in situations implying a certain risk, or even bigger in case of woodland on steeply sideways-sloping ground, in the line direction.

The problems of lower voltage lines are similar, since although the ROWs are narrower, the distance of the cables from the ground is obviously shorter, as the pylons are much smaller. For this reason these lines often cross wooded areas, increasing the fire risk. Therefore, the results of this study could be even more relevant to distribution networks than they are to ROW management in the high voltage network, since problems posed by the upkeep of their ROWs are even more difficult as the vegetation outgrows the safety limits faster.

## MEASURES TAKEN TO REDUCE THE IMPACT

It has become a basic principle of Red Eléctrica's management philosophy to take a series of measures designed to reduce, as much as possible, the damage provoked by its network. In the specific case of ROWs, the measures taken to reduce the impact of their opening and upkeep are basically twofold:

- to reduce ROWs to the essential minimum in the construction of new lines, according to dimensions agreed with the corresponding forestry and nature conservation agencies, and
- to redefine the areas to be treated in existing lines, reducing the cutting and regenerating affected areas.

On new lines these measures involve the following activities:

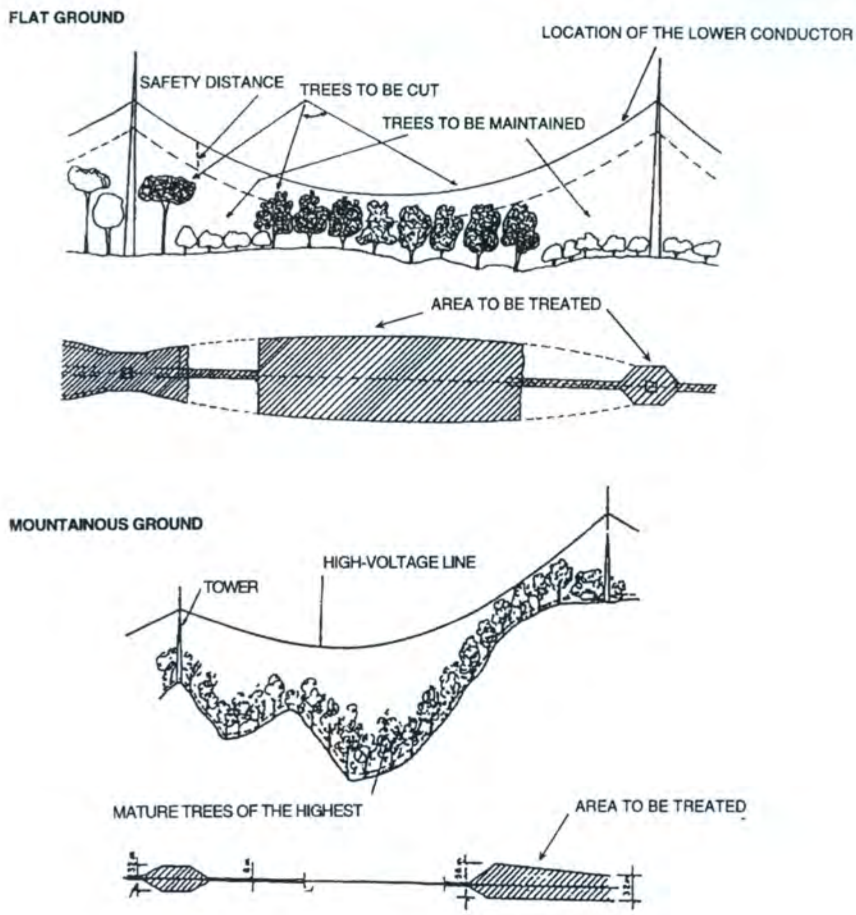



Fig. 3. Plant and elevation of a variable-width ROW.

*Avoiding routes through wooded zones*

The prime aim of Environmental Impact Studies is to locate and identify zones and spots that, in a very wide sense, could be affected by the project or represent an obstacle to its realization, whether for environmental, technical or legal reasons. The result of such studies is that the routes chosen for new lines have the lowest environmental impact possible. A comparative analysis of the possible alternatives is made to avoid a route through the most sensitive areas, especially through zones where ROWs would have to be opened up, or those in which the ecological value of the woodland crossed would mean a higher impact of the lines.

*Adjustment of ROW width*

Throughout the project the ROW width is determined in accordance with the location in each span of the line. For this purpose, a line profile study is carried out, analyzing the line needs at each point, taking into account the minimum distance defined in regulations and the characteristics of the existing plant formations. The ROW is determined in such a manner that its width adjusts to the characteristics of the line, the terrain and the plant formations in each section. The result is a variable width ROW, reduced to that strictly necessary at each point of the line for a long-term safety distance free of tree vegetation (Fig. 3).

In existing lines, actions will be conditioned by the design criteria followed in each project, so previous studies would be necessary in each case to decide the necessary measures to reduce the impact of the ROW.

*Redefinition of the ROW*

Factors to be analyzed in the studies of existing lines include the following: protected natural sites of all types affected by each line, the plant formations crossed, as well as their interest, etc. These studies allow the analysis of the current situation of each line. This knowledge allows the ROW width to be redefined, following the above-mentioned criteria for new lines, so that the ROW may be adjusted to the present situation.

*Maintaining the scrub layer*

Many of the shrub formations of Spain have characteristics compatible with the lines, so an important measure in terms of reducing the aforementioned impact is simply not to remove them. However, this may sometimes not be possible where fire danger involves a risk for the line or where the species may block access, as in the case of cistus beds, heather, furze or gorse heaths, etc.

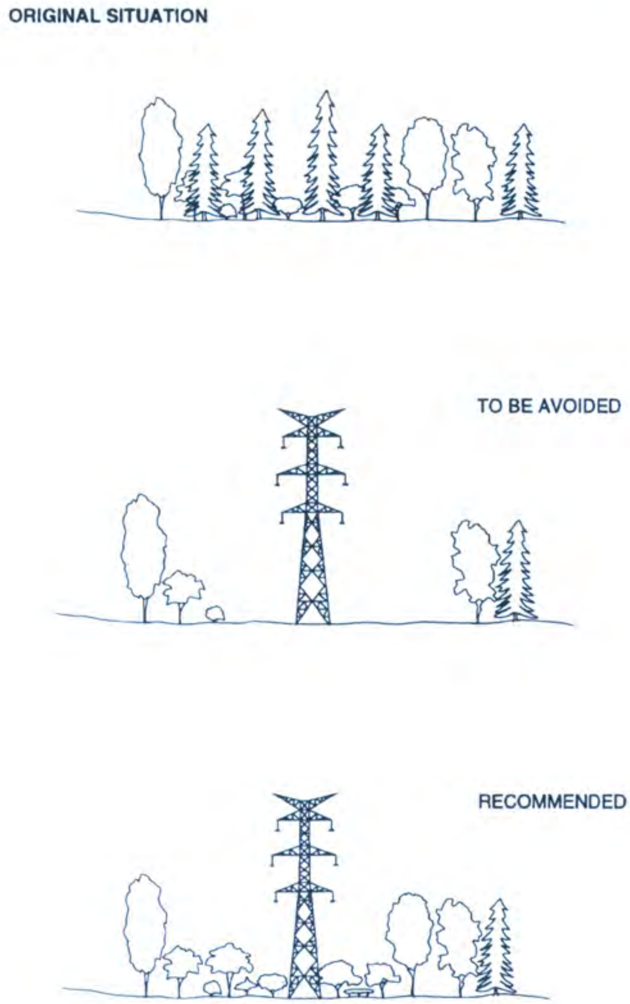



Fig. 4. ROW treatment through selective cut.

*Selective cutting*

After ensuring the safety of the line and the preservation of existing plant life, selective cutting involves removing the trees considered to represent danger or risk, while leaving the rest. This can be accomplished in various ways: cutting back the higher outgrowths and leaving the lower ones; cutting back the outgrowths of quickly growing species and leaving those that take longer to reach certain height, etc. (Fig. 4)

*Programmed ROW treatment*

The adoption of this method as a ROW treatment criteria has the long-term aim of ensuring that the plant life in the ROW is compatible with the line, leaving a longer interval between each pruning. The cutting is carried out to meet the safety criteria of the regulations and is extended to those trees that, within a certain time, could become unsafe, whereby a prediction has to be made of their growth rate (Fig. 5).

In general, the aim of programmed treatment is to eliminate the growing species that would involve a risk for the line within a time of not less than four or five years.

This process is complemented by structural pruning of all slow-growing tree species to ensure that their future development is compatible with the line in the long term. This involves a previous analysis of the plant formations and/or trees present. Once the current and future growth is known, a decision is taken to remove the tree or leave it standing, with the overall aim of cutting all trees that involve a risk.

This procedure could also involve the systematic removal of the outgrowths of all tree and shrub species not considered to be suitable, such as the pyrophilous species (those that spread the fire or which produce a lot of flames and smoke when burning) and fast-growing species (essentially those that grow to a significant height).

*Integral ROW treatment*

Integral ROW treatment is a further development of the above method, including other actions carried out at the same time to favor or even introduce species compatible with the line. The aim is to maintain permanent vegetation in the ROW to avoid the aesthetic impact and reduce all the other above mentioned impacts (erosion, etc).

After the programmed treatment, all appropriate measures are taken to favor the species considered to be suitable, such as their preservation, pruning around outgrowths and, where applicable, planting (Fig. 6). These species have to fulfil a number of basic condi-

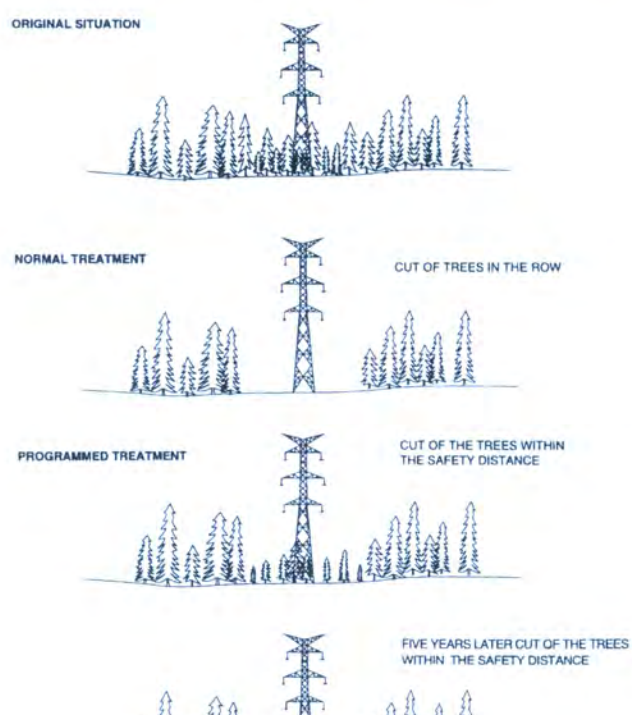



Fig. 5. Options for the treatment of ROW.

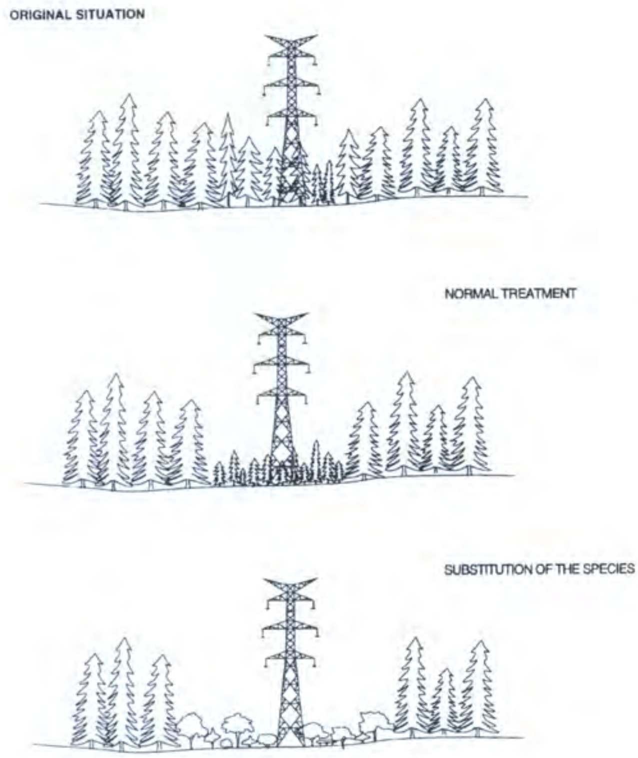



Fig. 6. Integral treatment of the ROW.

tions: they must be pyrofugous, they must cover a large area to crowd out competitors, they must have a soft stem (so as not to block passage throughout the ROW) and they must be a light-soil species (so that they will not invade existing pathways).

This sort of treatment is carried out in five phases:

- removal of tree growths or scrub incompatible with the line;
- preservation of protected or interesting species;
- maintaining and even widening the existing ROW, opening up the access;
- preserving and favoring species compatible with the line;
- completing the plant life coverage by introducing compatible species, if not already achieved with the above measure.

The decision to undertake the project described herein was conducted to be able to carry out this sort of work in the best way possible.

## DRAWING UP THE CATALOGUE OF IBERIAN VASCULAR FLORA COMPATIBLE WITH THE LINES

The drawing up the catalogue is designed to reduce the environmental impact attributable to the lines. The aim is to identify the suitable species for the ROWs, by creating a tool for the best possible management of the tree and shrub formations crossed by the lines; maintenance work in the ROWs would therefore be carried out at longer intervals and ideally, be practically unnecessary.

To meet this goal, the catalogue allows, working from the details of the woody species present, the identification of the species that are compatible with the lines for each of the basic ecosystems making up the Spanish flora, i.e., the species whose presence not only reduces the maintenance work but also improves the conditions of the ROW in the short, medium and long term, so that it may fulfil its function in the best way possible.

The following activities were undertaken:

- drawing up a catalogue of four hundred and fifty species (native and non-native);
- an examination of the characteristics of the species in terms of their greater or lesser compatibility with the lines;
- determination of comparison criteria; and
- creation of a relational database.

The list of species selected comprises the catalogue of the 450 species making up the group of higher-level woody species of the Iberian flora. Working from this, an analysis is then made of the morphological and ecological characteristics of those that could be considered to be suitable, in terms of how well they comply with the requisite characteristics.

The characteristics adopted as a base for the selection, not being exclusive, and keeping in mind that the species must satisfy the greatest number possible, are the following:

- that they belong to the flora of the area where they are to be promoted or introduced;
- that they have a limited height growth;
- that they are pyrofugous, i.e. they burn poorly and would slow down the spread of any fire;
- that they are highly competitive, i.e. they carpet the ground quickly and crowd out other species;
- that they posses a soft, easily breakable stem, at least in early growth stages; and
- that they be light-soil species, so they will not invade working paths.

The aim of the research work is a species-by-species analysis based on the above characteristics. This particular information means that the catalogue is not a conventional field guide of trees and shrubs. An in-depth analysis was necessary of aspects that would not normally be included in a guide.

Working from the details analyzed, a species file was drawn up including the following information.

### Identification

For each species or subspecies the scientific name considered as correct has been given, according to the Botany Nomenclature Code. After this comes the botanical family to which the taxon belongs. The common name is then given (up to three if there are different ones), these being the vernacular names by which the species in question is known, plus the register number of this file within the database. This number is correlative, following the alphabetical list of species, separated into two groups, one to four hundred including the native species and thereafter the introduced or non-native species.

### Structural information

Some details of the species have been included, such information includes the maximum height in meters (usually attained by each plant). A number code referring to a comparative silhouette giving its general aspect, which is then shown in a sketch alongside. For obvious practical reasons, a very limited number of silhouettes (30) have been chosen for this sketch. A reference figure is normally given alongside (a human figure of about 180 cm or a high-voltage pylon of about 40 m) to give a rough idea of the height of the plant.

A reference is then made to the life form of each one (biological or biotypical forms), grouped into trees, shrubs, scrub, perennial grasses and climbing grasses.

In terms of seasonality, plants have been classified into deciduous and evergreen. Marcescent plants, i.e. those that do not finally shed their leaves until the next spring, are included as deciduous. Also under deciduous have been included those foliate plants that shed their leaves in the hottest part of the summer (such as many gorse and broom species), as well as those that, without being strictly seasonal, lose their leaves early in the year and remain leafless thereafter.

Stem consistency aims to designate the woodiness of the plant in question, using the qualifications of woody, fruticose, suffruticose and herbaceous. An attempt is thereby made to segregate those that form wood strictly speaking (i.e., trees, small trees and tall shrubs such as holm oak, olives or strawberry tree, respectively), from those that form small woody stems (such as rosemary and furzes), from those that scarcely do so and only at the base, maintaining a herbaceous consistency in the remainder of the plant, and lastly classifying as herbaceous those plants that, albeit perennial, do not show any degree of woodiness.

The morphological description includes a short account of the morphological aspects characterizing the plant in question, both in the parts above the soil and in the root structure, if known.

### Biological information

The information contained in this section begins with a qualification of the taxon's capacity for regeneration by seed, expressed with four values (bad, average, good, very good).

Then comes an evaluation, using the same variables, of its aptitude for vegetative regeneration, including propagation by stolons, stumps (offshoots), from the root or by any special propagating method.

Stability of formation is the maintenance through time of the plant structure introduced, always concentrating on the environmental aspect, since it is obvious that the stability will vary in terms of its proximity at any particular point to the edge of its range, both in terms of latitude and height. This is a three-degree evaluation in order of increasing stability.

The growth rate is an attempt to show by four values (slow, medium, quick, very quick) the plant speed to reach its normal height. The growth rates are broken down into classes by biotype. Species that reach their maximum height quickly are considered to be fast-growing species, whatever this height may be.

### Environmental information

Under this heading is grouped all information on the areas where the plant grows. An upper and lower altitude limit is assigned (excluding exceptional or unrepresentative records), expressed as height above sea level.

Its phytoclimatic characterization is shown according to Allué's scheme. The relationship between Allué's phytoclimates and the number appearing in the files is as follows:

Type III (IV) and IV (III): Sub-Saharan phytoclimate
Type IV I: Arid Mediterranean phytoclimate
Type IV: Genuine Mediterranean phytoclimate
Type IV (VI) Sub-mediterranean phytoclimate
Type VI (IV) Sub-Atlantic phytoclimate
Type VI: Atlantic phytoclimate
Type VI (V): Atlantic tempered phytoclimate
Type VIII (VI) and X: Oroboreal, taiga and alpine phytoclimate

Then follows a qualification of the taxon in terms of its soil preferences, distinguishing calcifuge species, which avoid lime soils, from calcicole species, which usually grow on lime soils, and those that tolerate both soil types (edaphically neutral species). A mention is also made of its possible tolerance of soils rich in salts (halophile species), or chalky ground (gypsophiles) or its preference for soils with a build up of nitrogen. This last classification corresponds to species called nitrophiles with a preference for disturbed ground, roadside verges, rubble tips, waste dumps, wasteground, etc.

It should be pointed out that these six categories are not mutually exclusive, and there may be plants that are at once nitrophile and calcicole or neutral and nitrophile.

Another qualification in terms of soil type is made from a structural point of view, classifying plants as neutral or typical of heavy or light soils. This information is included under the heading of soil compactness. We take as light soils those that show a differentiated surface with a high level of disintegration. Heavy soils, allowing little passage of air, are characterized by a high proportion of clay or loam. In this section we have included stony soils and very thin soils.

Environmental information is completed by a dynamic characterization that attempts to fit each plant into one of the following dynamic stages: (a) pioneer (typical of the early stages of vegetational succession; these are generally colonizing or invading species, the typical sun-lovers of open, well-lit places); (b) intermediate stage; and (c) those typical of climax stages (i.e. the stages of greatest maturity and structural complexity in the vegetational succession; these are usually shade-loving species typical of more or less wooded formations). It may sometimes happen that the same taxon behaves as a pioneer and climax species; for example the birch tree (*Betula* spp.), which colonizes open spaces within moisture-loving formations, but sometimes remains as a stable community in specific environments (high mountains of northern areas, areas of rushing water, river banks, etc).

Finally, in the case of taxons that are singular for any reason (because of their distribution, their taxonomy, propagation system, etc), a mention is made within the observation section of the importance of their presence in a regional, general or local context (rarity, endemic species, bio-geographical splitting off, phyto-geographical limits of the taxon, etc). A series of notes on the habitat of the taxon has also been included in this section, where deemed of interest.

### General information

This section gathers all details of interest not already included in previous sections. An evaluation is thus made of the combustibility or ignitability of each plant, ranging from those of high combustibility (usually due to a content of resins or other flammable products, as is the case to a lesser or greater degree of pine trees and cistus plants) to those that burn less readily and those with low combustibility (such as the shrubby orache, *Atriplex halimus*). Also evaluated in this section is the ease of transplanting the formation generated by the plant in question, differentiating in this case only between those that give rise to formations or structures that are difficult to transplant, those that are fairly difficult and those that are easy to transplant.

Products offered by each plant are included in the products section, where their usefulness to man and animals is shown: fruits, resins, tannery products, firewood, pharmacology, wickerwork, etc.

Finally, a mention of the species with which the taxon most often coincides; for the sake of brevity the number of species with which it may live has been limited to a maximum of 10, in order of decreasing frequency. This information has not been included for non-native species, since it varies mainly in terms of where the exotic plant is cultivated.

Under the heading of "origin" of the species an indication is given of whether the taxon under consideration is native or non-native (exotic).

### Distribution

This section includes a brief account of the distribution on the Spanish peninsular and in the Balearic islands of the taxon under consideration. Given that it would be impossible in a work of this type to give an exhaustive distribution map based on all the records in the various botanical magazines or deposited in the various Spanish herbaria, reference has been made only to the provinces where its presence has been confirmed (whether by reference works or field work). It therefore follows that the initials of the province appear whether the plant has been recorded there as scarce or locally plentiful or widespread, so it would be just as well to cross-check this information against the species habitat (altitude, soil type, bioclimatic type, etc.). The file ends with a map showing the provinces.

For non-native species (which do not naturally occur in the area under consideration, i.e. they are exotic species) no reference is made to their Spanish distribution, since this is the outcome of arbitrary introductions effected by human activity.

### Line Compatibility Index (LCI)

To sum up the suitability of each species for the formation of vegetational cover in the ROWs a polynomial has been composed showing the most positive values for this objective, so the highest values correspond to the species most recommendable on the various grounds considered. It is obvious that this LCI (Line Compatibility Index) could sometimes hide low values in certain aspects that are relevant when programming activities.

In analysing this index it should be kept in mind that a high LCI does not necessary imply that a given species is compatible with the line in all cases. Each situation will depend on the lie of the land and the distance of the cables from the ground and from the tree tops. What the LCI does tell us, other things being equal, is whether or not a certain species in the ROW is compatible with the line in the long term and therefore whether or not it might need to be removed. Thus, a high LCI in a tree species indicates that, along with other favourable characteristics, it is slow growing and easy to control, so it is feasible to maintain it in the ROW, always providing that the respective safety distance is observed and that programmed treatments can be carried out. On the other hand, a high LCI in a shrub species means that it is a fast-growing species with a stem that never becomes too woody, that burns poorly and has no thorns, thereby complying with all the requisites.

Correct use of the catalogue presupposes a previous knowledge of the area crossed by the line, whether by province or by phytoclimatic region. Working from this information, an analysis will be made of those species existing in the zone that show the highest LCI. With this information and that provided by the catalogue of the species present, the necessary work may be undertaken to transform the existing vegetation, removing incompatible species (low LCI) and encouraging or introducing compatible native species (high LCI), taking on programmed or integral ROW treatment to obtain in the short term a compatible woodland coverage that stands in need of no maintenance work within a reasonable length of time.

## COMPUTER PROCESSING

The information collected has been introduced into a relational database management system (RDBMS). The software, FOXPRO 2.6. is based on Windows 3.1. and offers the following advantages:

- good compatibility with other database programmes;
- ease of use;
- possibility of incorporating graphical and memo fields (observations) containing the distribution, appearance and other attributes of each species;
- integration of the databases in GIS environments;
- possibility of developing other applications from the work carried out, such as expert systems, picture library, etc.

It may therefore safely be claimed that the software chosen for the entering and management of the information is flexible and versatile and has responded well to the problems posed by this work.

The database permits the addition of new species or the modification of any record introduced. The main function of the database is to allow examination of the catalogue once some file search conditions have been imposed. For example, a request may be made to give an alphabetic list of all calcicole species with a maximum height of less than 15 m that grow between 1,000 and 1,500 m of altitude with an LCI higher than 15.

## CONCLUSIONS

The taking of steps to minimise the impact of ROWs is becoming a basic factor both in the design and running of power lines; in some regions, as in Catalonia, it is a legal requirement. The adoption of these measures, however, is often limited by an ignorance of how the woodland concerned may react to their implementation. The tool herein described is an attempt, as far as possible, to remedy this lack of information. An analysis of the existing species and plant formations below the lines provides the line manager with the information necessary to decide which species have to be removed or encouraged. The power line manager can now use lists of compatible and incompatible species, as the case may be and depending on how the ROW is to be maintained.

## REFERENCES


Allué, M. 1990. Atlas fitoclimático de España. ICONA.

Arevalo, J. and J. Roig. 1992. Las líneas de transporte de electricidad y la cubierta vegetal. Rev. Tecnoambiente, no. 22 año 4. Noviembre pp. 80–87

Arevalo, J. and J. Roig. 1992. Métodos alternativos para el tratamiento de calles en el paso de líneas por masas arboladas. 1ª Jornadas Internacionales de Lineas Electricas y Medio Ambiente, Madrid, Mayo 1994. Libro de Comunicaciones, pp. 127–143.

Arevalo, J. 1994. Problemes poses par la flore dans la construction des lignes electriques en Espagne. Colloque International sur Lignes Electriques et Environnement. Metz, France 6–8 Juin 1994. Actes du Colloque, pp. 101–110.

Aseginolaza, C. et al. 1985. Catálogo florístico de Álava, Vizcaya y Guipúzcoa. Servicio Central de Publicaciones del Gobierno Vasco. Vitoria. 1149 pp.

Bolòs, O., J. Vigo, R.M. Masalles, and J.M. Ninot. 1990. Flora manual dels Països Catalans. Editorial Pòrtic, S.A. 1247 pp.

Castroviejo, S., M. Laínz, G. López González, P. Montserrat, F. Muñoz Garmendia, J. Paiva, and L. Villar. 1986–1993. Flora Iberica. Vol. I, II, III and IV. C.S.I.C.

Costa, M., C. Morla and H. Sainz. 1984. Táxones de interés corológico de la cuenca media del Duero. Anales Jard. Bot. Madrid, 41(2): 395–406.

Fernández Casas, J., R. Gamarra, and M.J. Morales Abad. 1992. De flora iberica index chartographicus. Treballs del Inst. Bot. Barcelona, 15: 422.

García Rollán, M. 1980. Claves para la Flora de España (Península y Baleares). Volumen I. Pteridófitas, Gimnospermas, Dicotiledóneas (A–J). Ediciones Mundi-Prensa. 675 pp.

García Rollán, M. 1983. Claves para la Flora de España (Península y Baleares). Vol. II. Dicotiledóneas (L–Z) y Monocotiledóneas. Ediciones Mundi-Prensa. 764 pp.

Jala, J. and J. Suominen. 1976. Atlas Florae Europaeae 3. Salicaceae to Balanophoraceae. Helsinki.

López González, G. 1982. La guía de INCAFO de los árboles y arbustos de la Península Ibérica INCAFO.

Moreno Rivero, L. 1995. Mapas 416 (adiciones) y 683-695. En: Asientos para un atlas corológico de la flora occidental, 23. J. Fernández Casas, R. Gamarra and M. J. Morales (eds.). Fontqueria, 42: 431–607.

Peinado, M. and S. Rivas-Martínez. 1987. La vegetación de España. Secretaria General de Publicaciones. Universidad de Alcalá de Henares. 544 pp.

Rameau, J.C., D. Mansion, and G. Dumé. 1989, 1994. Flore forestière française, I, II. Ministère de l'Agriculture et de la Forêt. Paris.

Raunkiaer, C. 1934. The Life Forms of Plants and Statistical Plant Geography. Oxford University Press, Oxford, England.

Rivas-Martínez, S. 1987. Memoria del mapa de series de vegetación de España. ICONA. 268 pp.

Ruiz de la Torre, J. and L. Ceballos. 1971. Árboles y arbustos de la España peninsular. Instituto Forestal de Investigaciones y Experiencias, E.T.S.I. Montes. Madrid. 512 pp.

Valdés, B., S. Talavera, and E. Fernández-Galiano, eds. 1987. Flora Vascular de Andalucía Occidental. 3 vol. Ed. Ketres.


## *BIOGRAPHICAL SKETCHES*


***Javier Arévalo-Camacho***

*Environmental Service, Red Eléctrica de España, S.A., Pº del Conde de los Gaitanes, 177, 28109 Alcobendas, Madrid, Spain*


Javier Arévalo-Camacho is a Forest Engineer and a specialist in Environmental Assessment. He has ten years' experience in environmental impact studies of power lines. He is interested in vegetation control and management, landscape studies and environmental impacts of power lines in general.

***Jorge Roig-Solés***
*Environmental Service, Red Eléctrica de España, S.A., P° del Conde de los Gaitanes, 177, 28109 Alcobendas, Madrid, Spain*

Jorge Roig-Solés is a Mining Engineer at the Polytechnic University of Madrid. He holds a Diploma in Environmental Engineering from the University of Strathclyde (Glasgow).

***Carlos Morla Juaristi***
***Fernando Gómez Manzaneque***
***Elena Bermejo Bermejo***
***Felipe Domínguez Lozano***
***Jesús Maza Pecino***
***Susana Molinero Herranz***
***Leoncio Moreno Rivero***
*Forest Botanical Department, Escuela Superior de Ingenieros de Montes, Universidad Politécnica de Madrid, Ciudad Universitaria, Madrid, Spain*

# Old Field Vegetation for Low Maintenance Highway Rights-of-Way

**Nancy P. Cain**

This paper documents research on old field or aster/goldenrod communities suitable for integrated vegetation management (IVM) of low maintenance highway rights-of-way (ROW) in Ontario. Field observation has identified twenty species that are found on highway ROW throughout the province, including Canada goldenrod, grass-leaved goldenrod, New England aster, tall white aster, flat-topped aster and heath aster. The literature indicates that a number of these aster and goldenrod species have allelopathic effects on herbaceous and woody species. This quality, the vigorous dense growth habit of many species and the underground rhizomes make these species highly suitable for highway ROW where control of noxious weeds, brush and erosion are major concerns. Options for using old field vegetation on roadsides include managing existing stands and seeding following construction. In many parts of the province, asters and goldenrods establish naturally providing solid or mixed stands of asters and goldenrods. These areas can be incorporated into IVM programs by identifying these areas and fostering their growth through selective maintenance programs. Aster/goldenrod seed mixtures were developed for Ontario conditions that could be used to establish old field vegetation on roadsides following construction. Seed costs ranged from $1,700 to $4,400 CDN per hectare ($500 to $1300 US per acre). Field experiments found that one to three years are required to establish plants and that a nurse crop is required to stabilize the seeding area while these plants develop.

*Keywords*: Roadside vegetation, integrated vegetation management, *Solidago* spp., *Aster* spp., seeding, allelopathy

## BACKGROUND

Vegetation management of provincial highway rights-of-way (ROW) in Ontario has evolved since the 1970s to reflect environmental concerns and fiscal constraints. The current maintenance program limits ROW mowing to areas where visibility is a safety concern such as approaching ramps and intersections. Mowing is generally limited to southern Ontario in areas of rural, agricultural or urban land use; highway ROW are not mowed in central and northern Ontario where forests predominate adjacent lands. Integrated Vegetation Management (IVM) programs have reduced herbicide use through selective applications that target problem areas. As a result of these approaches to highway ROW management in Ontario, many naturally occurring perennial species have flourished on highway ROW.

In the course of evaluating native perennial wildflowers suitable for ROW planting, it was observed that asters and goldenrods were widespread and prolific wildflowers in Ontario. These species were, in turn, identified as an important component of naturally occurring competitive vegetation as part of IVM programs for Ontario roadsides. IVM incorporates many management tools including selective maintenance and the use of competitive ground covers which prevent the establishment of undesirable species such as noxious weeds and brush.

The objective of this paper is to report investigations on the identity and characteristics of aster and goldenrod species commonly found on Ontario highways and to summarize the literature on the competitive and allelopathic qualities that make these species suitable for roadside IVM programs. The second part of this paper provides current recommendations for seed mixtures to establish aster/goldenrod communities suitable for Ontario roadside conditions and summarizes the results of field experiments evaluating the performance of aster/goldenrod seed mixtures planted in roadside conditions.

**Table 1. Aster and goldenrod species commonly found on Ontario Roadsides[1]**

| Scientific name | Common name | Height (cm) | Ont. distribution[2] | Soil moisture | Flowering time | Flower colour |
|---|---|---|---|---|---|---|
| *Aster ciliolatus* | Lindley's aster | 30–100 | N, C | moist–dry | Aug.–Oct. | pale to deep blue, yellow disc |
| *Aster cordifolius* | heart-leaved aster | 20–200 | S | | Aug.–Oct. | pale blue, yellow disc |
| *Aster ericoides (Virgulus ericoides)* | heath aster | 30–90 | S, C | mesic–dry | July–Oct. | white, yellow disc |
| *Aster laevis* | smooth(-leaved) aster | 20–100 | SW, C | mesic–dry | Aug.–Oct. | pale to dark blue, yellow disc |
| *Aster simplex (Aster lanceolatus)* | panicled aster | 30–150 | throughout | moist | Aug.–Oct. | white to pale pink, yellow disc |
| *Aster macrophyllus* | large-leaved aster | 10–150 | throughout | moist–dry | Aug.–Sept. | white to violet, yellow disc |
| *Aster novae-angliae (Virgulus novae-angliae)* | New England aster | 30–250 | S, C | moist–mesic | Aug.–Oct. | purple to pink, yellow disc |
| *Aster puniceus* | purple-stemmed aster | 40–250 | throughout | moist–mesic | Aug.–Oct. | pale to dark blue or purple, yellow disc |
| *Aster pilosus* | frost aster | 20–150 | S | dry | Aug.–Oct. | white, yellow disc |
| *Aster ptarmicoides (Solidago ptarmicoides)* | upland white aster | 10–40 | N, C | dry | June–Sept. | white, rarely pale yellow |
| *Aster umbellatus* | flat-topped white aster | 20–250 | throughout | dry–moist | Aug.–Sept. | white, yellow disc |
| *Aster sagittifolius (Aster urophyllus)* | arrow-leaved aster | 40–200 | S, C | dry | Aug.–Oct. | white to pale pink, white to pale yellow disc |
| *Solidago altissima* | late goldenrod | 50–200 | throughout | dry–moist | late Aug.–Nov. | yellow |
| *Solidago canadensis* | Canada goldenrod | 30–150 | throughout | moist–dry | mid July–Sept. | yellow |
| *Solidago gigantea* | tall goldenrod | 50–200 | throughout | moist | late July–Sept. | yellow |
| *Solidago graminifolia (Euthamia graminifolia)* | grass-leaved goldenrod | 30–120 | throughout | moist | July–Oct. | yellow |
| *Solidago juncea* | early goldenrod | 30–130 | throughout | dry | late June–Oct. | yellow |
| *Solidago nemoralis* | grey (-stemmed) goldenrod | 15–100 | throughout | dry | late June–Dec. | yellow |
| *Solidago rugosa* | rough-stemmed goldenrod | 30–200 | NE, C, S | moist–wet | Aug.–Oct. | yellow |
| *Solidago squarrosa* | stout goldenrod | 20–170 | throughout | dry | Aug.–early Oct. | yellow |

1 Compiled from personal observations, Fernald (1991), Pringle (1981), Semple and Heard (1987), Semple (1992), Sullivan and Daley (1981).
2 N: northern Ontario, NE: northeastern Ontario, C: central Ontario, S: southern Ontario, SW: southwestern Ontario; refer to Semple and Heard (1987) and Semple (1992) for more precise distribution.

## SUITABLE SPECIES FOR LOW MAINTENANCE ROW

The species of asters and goldenrods that are commonly found on highway ROW in Ontario are listed in Table 1. The scientific classification used in this table and throughout the paper follows Fernald (1991). The scientific classification proposed by Semple (Semple 1992; Semple and Heard 1987) is listed in brackets where it differs.

Certain species are present on specialized sites, such as the occurrence of smooth aster (*Aster laevis*) on prairie remnants in central and southwestern Ontario. Wet roadside areas are commonly populated by species such as *A. lanceolatus*, *A. puniceus*, *A. umbellatus*, *Solidago graminifolia* and *S. canadensis*. Clones of these species may occupy continuous areas resulting in large patches of solid flower colour, or mixed stands in wet areas or along roadside ditches. For example, continuous areas of *A. umbellatus* are common in central and eastern Ontario.

Mesic sites host species such as *A. ciliolatus*, *A. cordifolius*, *A. macrophyllus*, *A. ericoides*, *A. novae-angliae*, *S. graminifolia* and *S. canadensis*. The first three asters of this group are often found along shaded wood edges. *A. ericoides*, *A. sagittifolius* and *S. nemoralis* grow on dry, sandy, gravelly or rocky sites. *S. nemoralis* grows in solid strips along gravel shoulders in parts of central Ontario.

Aster and goldenrod species are challenging to identify in the field. Two excellent references, Semple and Heard (1987) and Semple (1992), provide detailed botanical descriptions of Ontario species. Two complimentary keys were written by Pringle (1968, 1981).

A number of goldenrod and aster species have demonstrated allelopathic abilities that reduce seedling establishment and/or growth of herbaceous or woody species. Aster and goldenrod inhibition of woody plant establishment has been observed in ROW management studies and experimental evaluations. Egler (1953) observed that several *Solidago* species produced dense cover that deterred tree seedling invasion in the northeastern United States, including *S. altissima, S. aspera, S. graminifolia, S. juncea* and *S. rugosa*. Bramble et al. (1990) classified *S. graminifolia* and *S. rugosa* as being highly resistant to tree invasion on electric transmission ROW.

Extracts of *S. juncea* and *S. uliginosa* inhibited germination of jack pine seeds by 89–98% and *S. juncea* extracts inhibited height growth of jack pine seedlings (Brown 1967). *A. macrophyllus* leaf extracts did not inhibit jack pine germination, which indicates that not all species are effective. Horsley (1977) found that *S. rugosa* and *A. umbellatus* extracts inhibited black cherry seed germination and foliage extract and root washes inhibited seedling shoot growth and dry weight accumulation. This inhibitory effect was observed in the field for up to one year after the aster and goldenrod were weeded out of the test areas. Similarly, Fisher et al. (1978) found that soil residues from old field vegetation inhibited growth of maple seedlings for two years after the old field vegetation was removed. The original vegetation included *A. nova-angliae, S. canadensis* and *S. graminifolia.* Fresh and rotted foliage extracts of *A. nova-angliae, S. canadensis* and *S. graminifolia* inhibited sugar maple seed germination and seedling root growth. Extracts of mulch from both species reduced the growth and nutrient content of sugar maple seedlings.

This allelopathic effect applies to herbaceous species as well. Jackson and Willemsen (1976) found that *A. pilosus* inhibited the germination of ragweed (a noxious weed in Ontario) and wild radish. Ichihara et al. (1978) isolated two polyacetylene compounds from underground stems of *S. altissima* which both inhibited the growth of millet seedlings. Kobayashi et al. (1980) extracted polyacetylene compounds from *S. altissima* plants and from the soil bordering *S. altissima* communities. Concentrations found in the plant tissue and the soil were inhibitory to the growth of herbaceous seedlings.

The ability of some aster and goldenrod species to interfere with woody and herbaceous seedling establishment and growth provides an additional tool for control of noxious weeds and woody vegetation. Many of these species provide dense, competitive cover suitable for low maintenance highway ROW.

## SELECTIVE MAINTENANCE

Wherever possible, selective maintenance should be practised to conserve areas where aster and goldenrods have established naturally. These plants have been provided at no cost to the highway operator and have established according to the moisture and light/shade requirements of the individual species. All of these species are perennial and many spread by underground rhizomes which provide soil stabilization.

Maintaining this beneficial vegetative cover should include limiting construction disturbance of these areas if possible. Preconstruction planning and site evaluation could flag important species and incorporate them in the design of the highway. Leaving perennial vegetation intact as much as possible will reduce re-establishment and long term maintenance costs.

Egler (1953) notes that goldenrod species were easily disturbed by herbicide applications and generally did not recover. Repeated mowing also reduces the growth of aster and goldenrod species. These disturbances could lead to bare areas which were originally covered by perennial vegetation. Repeated broadcast herbicide applications would reduce the competitiveness and vigor of existing plants if they were not completely killed. The resulting exposed area would be open to establishment of noxious weeds and other undesirable species. Herbicide application to established areas could be avoided by the use of spot applications or by using broadcast herbicide application only along sections of ROW where target species are present and then turning off the herbicide application where desirable species such as asters and goldenrods are present.

Cultural practices that promote the vigour of these areas such as fertilization could be an option. Bakelaar and Odum (1978) studied the effect of two treatments of granular fertilizer, 560 kg $ha^{-1}$ 6–12–12 in November and 448 kg $ha^{-1}$ 12–12–12 the following April on a old field community dominated by *S. canadensis*. The total net production of the area increased by 1.75 times, while the proportion present as *S. canadensis* increased from 40 to 55%. Other measures of relative importance of *S. canadensis* as a dominant in this vegetation community increased significantly in response to fertilization. In contrast, fertilization reduced the proportion of *A. pilosus* from 13 to less than 1%. The proportion of *Daucus carota*, considered to be a noxious weed in Ontario, fell from 1.5 to 0.2%.

## RECOMMENDED OLD FIELD SEED MIXTURE

A seed mixture was developed (Table 2) with the goal of establishing old field aster and goldenrod vegetation on highway ROW, incorporating the results of field observations and literature investigations. The seed mixture includes species suitable for a range of soil conditions from moist to dry in order to allow one seed mixture to be used on the entire ROW. For northern parts of the province, *A. ptarmicoides* could be substituted for *A. novae-angliae.* Another option is to use separate old field seed mixtures for wet or dry conditions (Table 3).

**Table 2. Recommended old field seed mixture with nurse grasses for highway right-of-way planting in Ontario**

| Scientific name | Common name | Rate of PLS ($kg\ ha^{-1}$) |
|---|---|---|
| *Aster ericoides* or | heath aster or | 0.11 |
| *Aster pilosus* | frost aster | |
| *Aster simplex* | panicled aster | 0.16 |
| *Aster novae-angliae*[1] | New England aster | 0.30 |
| *Aster puniceus* | purple-stemmed aster | 0.30 |
| *Aster umbellatus* | flat-topped aster | 0.73 |
| *Solidago canadensis* | Canada goldenrod | 0.25 |
| *Solidago graminifolia* | grass-leaved goldenrod | 0.06 |
| *Solidago nemoralis* | grey-stemmed goldenrod | 0.09 |
| Total | | 2.00 |
| Nurse grasses: | | |
| *Avena sativa* | oats | 25 |
| *Lolium multiflorum* | annual ryegrass | 25 |
| *Lolium perenne* | perennial ryegrass | 15 |

1 For sites in northern Ontario substitute:
*Aster ptarmicoides* upland white aster 0.30
PLS = pure live seed.

**Table 3. Old field seed mixtures for wet and dry sites**

| Scientific name | Common name | Rate of PLS ($kg\ ha^{-1}$) |
|---|---|---|
| (a) Dry Area Old Field Seed Mixture: | | |
| *Aster ericoides* or | heath aster or | 0.24 |
| *Aster pilosus* | frost aster | |
| *Aster novae-angliae* | New England aster | 0.66 |
| *Aster ptarmicoides* or | upland white aster or | 0.65 |
| *Aster sagittifolius* | arrow-leaved aster | |
| *Solidago nemoralis* | grey-stemmed goldenrod | 0.19 |
| Total | | 1.75 |
| (b) Wet Area Old Field Seed Mixture: | | |
| *Aster simplex* | panicled aster | 0.22 |
| *Aster novae-angliae* | New England aster | 0.42 |
| *Aster puniceus* | purple-stemmed aster | 0.42 |
| *Aster umbellatus* | flat-topped aster | 1.01 |
| *Solidago canadensis* | Canada goldenrod | 0.34 |
| *Solidago graminifolia* | grass-leaved goldenrod | 0.08 |
| Total | | 2.5 |
| Nurse grasses for use with both mixtures: | | |
| *Avena sativa* | oats | 25 |
| *Lolium multiflorum* | annual ryegrass | 25 |
| *Lolium perenne* | perennial ryegrass | 15 |

PLS = pure live seed.

The species in these mixtures are generally available from wildflower or prairie seed producers, although availability of individual species varies from year to year. The mixtures provide an even number of seeds of each species to provide a total of 600 to 750 seeds $m^{-2}$. This follows a model from wildflower establishment to use 500–1000 seeds $m^{-2}$. Use of a nurse grass mixture such as oats, annual ryegrass and perennial ryegrass (Table 2) is recommended to provide initial cover.

## SEED COST AND AVAILABILITY

Quality seed may be more readily available for species with an established commercial value such as New England aster. It may be more difficult to find a supplier of Canada goldenrod seed, although some suppliers will collect seed for special orders.

Costs range from $1,700 to $4,400 CDN per hectare ($500 to $1300 US per acre) (1995 supplier prices) assuming recommended pure live seed rate is required. The cost could be greater in light of lower seed purity or germination. This cost is greater than basic grass seed mixtures but in the range of other specialty seed mixtures. The cost could be recovered in reduced maintenance costs of the area once the plants are established, such as no mowing or fertilizing and reduced weed control costs.

Seed costs could be also be reduced by reducing the proportion of seed apportioned to more costly species or by using a mix that is targeted at wet or dry areas, therefore eliminating the need for some species. Seeding of one or two species may be another option.

As with wildflower planting, it is important to test the seed for purity and germination prior to planting in order to calculate the actual amount of seed that is required to obtain the desired amount of pure live seed (PLS). In some crop years, there may be many empty or immature seeds due to poor weather conditions or the fact that seed may have been collected at an immature stage. If the seed has not been cleaned fully, there may be varying amounts of stems, leaves, seed heads and other chaff. Both these factors reduce seed purity. Finally, seed may have deteriorated due to poor storage conditions or due to age of the seed which may reduce the amount of viable seed.

Experience in ordering aster and goldenrod seed from different suppliers over a period of years indicates that germination and purity of these species can be quite variable (Tables 4 and 5). Tetrazolium testing (a chemical test of seed viability) may be of value to establish germinable seed where seed dormancy is a problem (Table 5).

## SEEDING EXPERIMENTS

### Objectives

The objectives of these experiments were to evaluate the performance of an old field seeding mixture in terms of establishing aster and goldenrod species and to monitor the development of ground cover over the initial years following seeding. This is important in determining whether effective cover is established initially to provide erosion control and to determine

**Table 4. Germination and purity recorded from seed orders and results of commercial testing laboratories**

| Species | Germination range (batches) | Purity range (batches) |
|---|---|---|
| *Aster ericoides* | 0–82 (7) | 51.4 (1) |
| *Aster laevis* | 0–86 (5) | 60.2–97.4 (3) |
| *Aster simplex* | 0–5 (5) | 97.5 (1) |
| *Aster novae-angliae* | 3–92 (8) | 96.6–99 (2) |
| *Aster puniceus* | 5 (1) | – |
| *Aster umbellatus* | 0–51 (5) | 97.5 (1) |
| *Solidago canadensis* | 31–72 (3) | – |
| *Solidago graminifolia* | 0–88 (4) | 2.19 (1) |
| *Solidago nemoralis* | 32.5–100 (7) | 97.5 (1) |
| *Solidago ptarmicoides* | 65–86 (2) | 97.4–98 (2) |

**Table 5. Comparison of germination and tetrazolium test results on the same seed samples by commercial seed analysis laboratories**

| Species | Tetrazolium test | Germination test | Germination treatment[1] |
|---|---|---|---|
| *Aster ericoides* | 44 | 36 | 20°C T.B.[2] |
| *Aster ericoides* | 81 | 0 | 25°C T.B. |
| *Aster simplex* | 84 | 3 | Pre-chilled 6 days at 5°C |
| *Aster simplex* | 64 | 5 | 25°C T.B. |
| *Aster novae-angliae* | 82 | 55.5 | 15–25°C T.B. |
| *Aster novae-angliae* | 69 | 27 | $KNO_3$ 20°C petridish |
| *Aster novae-angliae* | 75 | 66 | 15–25°C T.B. |
| *Aster novae-angliae* | 87 | 3 | 25°C T.B. |
| *Aster umbellatus* | 71 | 2 | Pre-chilled 6 days at 5°C, 25°C T.B. |
| *Aster umbellatus* | 63 | 0 | 25°C T.B. |
| *Solidago canadensis* | 70 | 72 | Pre-chilled 5 days at 5°C, 15–25°C T.B. |
| *Solidago canadensis* | 77 | 55 | Pre-chilled 7 days at 5°C, 15–25°C T.B. |
| *Solidago graminifolia* | 63 | 0 | 10°C top of blotter |
| *Solidago nemoralis* | 89 | 68 | $KNO_3$. Pre-chilled 14 days at 5°C. 25°C petridish |
| *Solidago nemoralis* | 48 | 32.5 | $KNO_3$. Pre-chilled 14 days at 5°C. 20–30°C petridish |
| *Solidago nemoralis* | 87 | 6 | 25°C T.B. |

1 Procedures following: Association of Official Seed Analysts (AOSA). 1993. Rules for Seed Testing. Journal of Seed Technology 16 (3) and AOSA. Feb. 1986. Species without AOSA Testing Procedures. Journal of Seed Technology 60 (2).
2 Top of blotter

the success of seeding as a method for establishing an old field community. In earlier experiments by the author testing wildflower and prairie seed mixtures, it was observed that New England aster, heath aster, smooth aster and upland white aster took one or two years to establish plants which grew slowly and did not flower until two or three years after planting.

## Methods

Experiments to evaluate the performance of an old field mixture were established in 1993 on Highway 410 in Mississauga, Ontario (light industrial adjacent land use) and in 1994 on Highway 63 about 30 km east of North Bay, Ontario (forested region). A randomized complete block design was used at each site with four blocks that were located on different sections of the same highway. The experimental units were 9×10 m or 6×13 m, depending on the width of the ROW. Two of the blocks planted on Highway 410 were lost to construction after the second growing season.

On Highway 410 the seeding treatments were an undisturbed control, an unseeded control, an old field seed mixture (Table 6) and an old field seed mixture plus a nurse grass mixture of oats, annual ryegrass and perennial ryegrass. In the Highway 63 experiment, the treatments were an undisturbed control, an unseeded control and an old field seed mixture plus nurse grasses (Table 6). The decision was made not to include the old field treatment without nurse grasses due to the slow rate of establishment of the old field species observed in the Highway 410 experiment. The seed mixture varied slightly between the two experiments in terms of species composition and seeding rate due to seed availability. In light of the location, the more southern species (*A. ericoides* and *A. novae angliae*) were replaced by *A. ptarmicoides*.

Existing ROW vegetation was killed the year before with 4.3 kg ha$^{-1}$ glyphosate herbicide (12 l ha$^{-1}$ Roundup). Where regrowth occurred, the area was resprayed the following growing season prior to planting. The sites were rototilled prior to planting. The soil on Highway 410 was a clay loam with 4.3–4.9% organic matter and pH ranging from 6.5 to 7.4. The soil on Highway 63 was a loamy sand with 3.4–3.6% organic matter and pH ranging from 5.1 to 5.7 (soil samples taken on adjacent site).

The Highway 410 site was seeded on June 18 (2 blocks) and August 5 (2 blocks), 1993 using a Wintersteiger Plotman self-propelled plot drill set up for no-till. Fertilizer was applied to all plots on Highway 410 except the undisturbed control, 50 kg ha$^{-1}$ nitrogen and 80 kg ha$^{-1}$ phosphorus according to soil test results. The planting of the last two blocks was delayed due to weather conditions. Heavy rain for two consecutive weekends after planting the first two blocks rendered the remaining planting sites too wet to accommodate the rototiller or seeder until mid-July. The decision was made to delay planting until August until weather conditions were more favorable for seed establishment.

A rainfall of 2.5 cm occurred the day after planting the initial 2 blocks which firmed the seedbed. The second two blocks were rolled after planting.

**Table 6. Composition of old field seed mixtures planted in experiments on Hwy 410, Mississauga in 1993 and Highway 63, east of North Bay in 1994**

| Species | Common name | Rate of PLS kg ha$^{-1}$ | |
|---|---|---|---|
| | | Hwy 410 | Hwy 63 |
| *Aster ericoides* | heath aster | 0.074 | – |
| *Aster laevis* | smooth aster | 0.333 | 0.210 |
| *Aster simplex* | panicled aster | 0.148 | 0.020 |
| *Aster novae-angliae* | New England aster | 0.277 | – |
| *Aster umbellatus* | flat-topped aster | 0.669 | 0.629 |
| *Erigeron philadelphicus* | Philadelphia fleabane | 0.214 | – |
| *Solidago canadensis* | Canada goldenrod | 0.226 | 0.213 |
| *Solidago graminifolia* | grass-leaved goldenrod | 0.054 | 0.396 |
| *Solidago nemoralis* | grey-stemmed goldenrod | 0.074 | 0.070 |
| *Solidago ptarmicoides* | upland white aster | – | 0.148 |
| Total | | 2.069 | 1.686 |
| Nurse Grasses: | | | |
| *Avena sativa* | oats | 25 | |
| *Lolium multiflorum* | annual ryegrass | 25 | |
| *Lolium perennis* | perennial ryegrass | 15 | |

PLS = pure live seed.

The Highway 63 site was seeded on 23 and 24 August 1994 using a Truax wildflower seeder with cultipacker. Contact seeding was used for both trials to ensure good seed/soil contact. The two seeding methods were comparable since in both cases the seed was deposited on the soil surface and mixed with chains, and the seed bed was firmed after seeding.

The plots were sampled using a 1 m$^2$ area which was evaluated for total cover, planted species and grasses. Evaluations were made of the cover of planted species in the whole plot as well. The presence or absence of planted species was noted. Data was analyzed for treatment effects using SAS (SAS Institute Inc., Cary, NC) GLM procedure for analysis of variance. The data were checked to ensure that they met normality and other ANOVA assumptions using the Shapiro-Wilk test statistic for normality and tests for homogeneity of variance (SAS, Univariate procedure). The data was subjected to a logit transformation for analysis (Snedecor and Cochran 1989) and the means were back-transformed to the original units of percentage for presentation.

## Results and Discussion

In the Highway 410 experiment, two years after planting, both the old field mixture treatment and the old field mixture plus nurse grasses treatment provided over 74% ground cover (Table 7). This compared to 90.6% ground cover in the undisturbed control and 65% ground cover in the unseeded treatment (Trmt effect: $P = 0.0025$). A number of the planted species occurred spontaneously on the site. Heath aster, New England aster, panicled aster and Canada goldenrod seedlings were observed in the seeded treatments (Table 7), but the cover of these species was significantly less compared to the undisturbed control (Trmt effect: $P = 0.0005$). Perennial rye grass made up the major grass cover in the old field plots seeded with nurse grasses compared to perennial and annual weed grasses with the other treatments (Trmt effect: $P < 0.0001$).

Four years after planting the total ground cover had decreased to 49% in the old field with nurse grass treatment, while it had increased to more than 78% in the unplanted control and the old field mixture seeded alone (Table 8). In contrast the area of grass cover fell to less than 8% in the old field treatment seeded with nurse grasses, compared to over 37% grass cover in the other plots (Trmt effect: $P = 0.0388$).

The best cover of old field species tended to be in the

**Table 7. Cover in response to seeding treatment two years after planting on existing highway right-of-way on Highway 410, Mississauga**

| Treatment | Cover (% area)[1] | | |
|---|---|---|---|
| | Planted species | Grasses | Ground cover |
| Undisturbed control | 28.6 | 43.4 | 90.6 |
| No seed mixture | 12.8 | 26 | 65.6 |
| Old field seed mixture | 17.5 | 11.4 | 74.1 |
| Old field seed mixture with nurse grasses | 14.9 | 21.5 | 78.4 |

1 Each mean represents 4 blocks and is the mean of the logit transformed data back-transformed to the original units of percentage area.

**Table 8. Cover in response to seeding treatment four years after planting on existing highway right-of-way on Highway 410, Mississauga**

| Treatment | Cover (% area)[1] | | |
|---|---|---|---|
| | Planted species (whole plot) | Grasses | Ground cover |
| Undisturbed control | 20.0 | 74.4 | 92.1 |
| No seed mixture | 14.5 | 37.6 | 78.4 |
| Old field seed mixture | 14.4 | 50.3 | 82.5 |
| Old field seed mixture with nurse grasses | 37.9 | 7.9 | 49.3 |

1 Each mean represents two blocks and is the mean of the logit transformed data back-transformed to the original units of percentage area.

treatment seeded with the old field seed mixture with nurse grasses, a mean of 37.9 (overall plot rating) compared to less than 20% with the other treatments (Trmt effect: $P = 0.0998$). The planted old field species represented a large proportion of the total cover with this treatment, 76.9%, compared to less than 20% with the other treatments. The following species were observed in both old field treatments: heath aster, panicled aster, New England aster, flat-topped aster, grassed-leaved goldenrod and Canada goldenrod. In addition, smooth aster and grey-stemmed goldenrod were observed in the plots seeded with the old field mixture alone. Species such as New England aster, panicled aster, heath aster, Canada goldenrod and grass-leaved goldenrod were not fully developed in height compared to existing plants in adjacent roadside areas.

The perennial ryegrass has lasted for three years and seems to have promoted the establishment of the planted species compared to seeding without nurse grasses. Although there may be volunteer old field species in the seeded plots, the seeding treatment plus nurse grasses seems to have resulted in a increased stand of these species and establishment of species not previously on the site such as flat-topped aster.

In the Highway 63 experiment, two years after planting, all treatments had over 90% total ground cover. The nurse grasses formed a major part of this cover in the old field treatment. The seeded species covered 7% in the sample area or 13.4% over the whole plot in the old field treatment compared to 0 in the control treatments. The cover of seeded species in the old field treatment was patchy which was observed with other wildflower and prairie seed mixtures planted in a companion experiment on the same site. This may have been due to interference of volunteer plants or due to patchy topsoil quality.

Seedlings of all of the species that were planted were observed in the old field treatment although many were too young to flower. The late summer planting may have been a factor in the slow development of the plants. Many of the planted species occurred naturally on the adjacent ROW, but additional species such as *A. laevis*, *A. ptarmicoides*, *A. umbellatus* and *S. nemoralis* established as a result of the seeding.

It will be necessary to observe these plots for a few more years to see if the plants in the seeded treatments flourish, spreading by rhizomes or woody rootstocks or by seed, depending on the species. Research is continuing to evaluate hydraulic seeding techniques for an old field seed mixture and to demonstrate the performance of this seed mixture with broadcast seeding on different sites.

## CONCLUSIONS

Aster/goldenrod old field communities are suitable for integrated vegetation management (IVM) of low maintenance highway rights-of-way (ROW) in Ontario where control of noxious weeds, brush and erosion are major concerns. Asters and goldenrods provide quality highway ROW vegetation due to the dense growth habit, the underground rhizomes of many species and the ability to exclude weeds and tree seedlings due to competitive or allelopathic interference. An added benefit is the aesthetic quality of the flowers from late summer to the end of the growing season. Options for using old field vegetation on roadsides include managing existing stands and seeding following construction.

Natural establishment of asters and goldenrods on highway ROW provides low cost, perennial cover that is highly competitive and suited to the growing conditions on each site. Established ROW areas should be managed to minimize disturbance of these desirable species by applying selective herbicide application programs, by avoiding mowing of these areas and by minimizing disturbance during construction if possible.

Three old field seed mixtures have been developed that are suitable for roadsides. Seeding experiments with old field mixtures were successful in establishing aster and goldenrod plants in highway ROW conditions. The seedlings germinated over a number of years and developed slowly, not flowering for two to four years after planting. The use of a nurse crop seemed to improve the success of the seed mixture. Due to the slow establishment, it is recommended to use nurse grasses with these old field seed mixtures to provide cover and prevent erosion during the initial period after seeding.

## ACKNOWLEDGEMENTS

The author would like to acknowledge the input of Andy Stripnieks and Nick Close, Ministry of Transportation, during this research project. The assistance of Ministry District staff located in Toronto, North Bay and Sudbury with the field research was greatly appreciated. William Matthes-Sears of the Ashton Statistical Consulting Laboratory, University of Guelph provided advice on experimental design and analysis.

## REFERENCES

Bakelaar, R.G. and E.P. Odum. 1978. Community and population level responses to fertilization in an old-field ecosystem. Ecology, 59(4): 660–665.

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. Journal of Arboriculture, 16(5): 130–135.

Brown, R.T. 1967. Influence of naturally occurring compounds on germination and growth of jack pine. Ecology, 48(4): 542–546.

Egler, F.E. 1954. Vegetation management for rights-of-way and roadsides. Annual Report of Board of Regents of the Smithsonian Institution, 1953 Publication 4149: 299–322.

Fernald, M.F. 1991. Gray's Manual of Botany. Dioscorides Press, Portland, Oregon. pp. 1381–1413.

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.

Horsley, S.T. 1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research, 7: 205–216.

Ichihara, K., T. Kawai and M. Noda. 1978. Polyacetylenes of Solidago altissima L. Agricultural Biological Chemistry, 42(2): 427–431.

Jackson, J.R. and R.W. Willemsen. 1976. Allelopathy in the first stages of secondary succession on the peidmont of New Jersey. American Journal of Botany, 63: 1015–1023.

Kobayashi, A., S. Morimoto, J. Shibata, K. Yamashita and M. Numata. 1980. $C_{10}$-polyacetylenes as allelopathic substances in dominants in early stages of secondary succession. Journal of Chemical Ecology, 6(1): 119–131.

Pringle, J.S. 1968. The common Solidago species (goldenrods) of southern Ontario. Technical Bulletin No. 2, Royal Botanical Gardens, Hamilton, Ontario. 15 pp.

Pringle, J.S. 1981. The common Aster of southern Ontario. Technical Bulletin No. 2 (Revised), Royal Botanical Gardens, Hamilton, Ontario. 15 pp.

Semple, J.C. and S.B. Heard. 1987. The asters of Ontario: Aster L. and Virgulus Raf. (Compositae: Astereae). Biology Series No. 30. Department of Biology, University of Waterloo, Ontario. 88 pp.

Semple, J.C. 1992. Goldenrods of Ontario: Solidago and Euthamia. Revised Edition. Biology Series No. 36. Department of Biology, University of Waterloo, Ontario. 88 pp.

Snedecor, G.W. and W.G. Cochran. 1992. Statistical Methods. Eighth Edition. Iowa State University Press, Ames, Iowa. pp. 428-430.

## *BIOGRAPHICAL SKETCH*

***Nancy Cain***

*Ontario Ministry of Transportation, Research and Development Branch, 1201 Wilson Avenue, Room 331 Central Building, Downsview, Ontario, Canada, M3M 1J8*

Nancy Cain is a Research Scientist with the Ontario Ministry of Transportation with training in weed science, tree physiology and horticultural science. Current research projects deal with mitigation of effects of salt on roadside plants; planting of native plants, wildflowers and competitive vegetation; and integrated vegetation management, especially the use of naturally occurring plant species.

# New Aspects of Rights-of-Way Management for High-Voltage Power Lines

**Reinhard Draxler, Dirk Uther, Gerhard Praxl, and Franz Hofbauer**

The general characteristics for the design and construction of high-voltage lines (technical parameters, economical requirements, laws and regulations, environmental and social aspects) have changed dramatically over the past decade. Most of the criteria that may arise are closely related to environmental subjects. The subject of rights-of-way maintenance and its complex profile of requirements has become an increasingly important factor. A cost-effective implementation of appropriate vegetation management programs requires a large number of different considerations. This paper deals with the development of new strategies for rights-of-way maintenance. Criteria for implementation of proper management programs, according to their different regional characters, are pointed out. Furthermore, a suggestion for a concept of a long-term oriented vegetation management program is described. Finally the important role of public participation and the integration into a company's Environmental Management System is discussed.

*Keywords*: High-voltage power line, Rights-of-way management, long-term oriented vegetation management program, environmental management system

## INTRODUCTION

The European electricity supply is determined by four independent joint grid operations organisations (UCPTE, Nordel, IPS, National Grid). The members of the largest — the UCPTE (Union for the Coordination of Production and Transmission of Electricity) — are Belgium, Germany, Spain, France, Greece, Italy, Slovenia, Croatia, Bosnia-Hercegovina, the south eastern regions of former Yugoslavia, Luxemburg, The Netherlands, Austria, Portugal and Switzerland. The UCPTE interconnection grid has a total generating power capacity of more than 380 GW. For transmission AC-lines with a frequency of 50 Hertz are used. The high voltage grid of *Verbund* (Austrian Electricity Supply Board) and *RWE Energie AG* is operated according to the specific technical rules of the Act on Electrical Engineering, as well as the framework of national and international obligations, which result from contracts with specific customers and partners. Also UCPTE standards have to be fulfilled by the power companies.

*Verbund* is the most important electricity supplier in Austria. The electricity generated covers over 50% (29 TWh) of the electrical demand in Austria. On average, more than 90% of this electricity is generated by means of hydro power and about 10% by thermal power. *Verbund* itself owns and operates the supra-regional high-voltage grid and ensures that in Austria electricity production and its demand is leveled out. With this task in mind, *Verbund* also imports and exports electricity. The *Verbund* high-voltage grid includes 32 substations as well as 3,600 km (2,200 miles) of overhead lines.

The *RWE Energie AG* was founded in 1898 and has become the largest private utility company in Europe. The total electricity release amounts to more than 125 TWh. *RWE Energie AG* has approximately 700 substations and its power line system exceeds close to 21,100 km (13,000 miles). The electricity is drawn from different sources of energy such as soft coal (51%), nuclear power (22%), hard coal (20%), water, gas and oil (7%).

Both companies *Verbund* as well as *RWE Energie AG* represent typical European utility companies. Their high voltage transmission lines cover wide parts of typical European landscapes, densely populated areas and natural countryside.

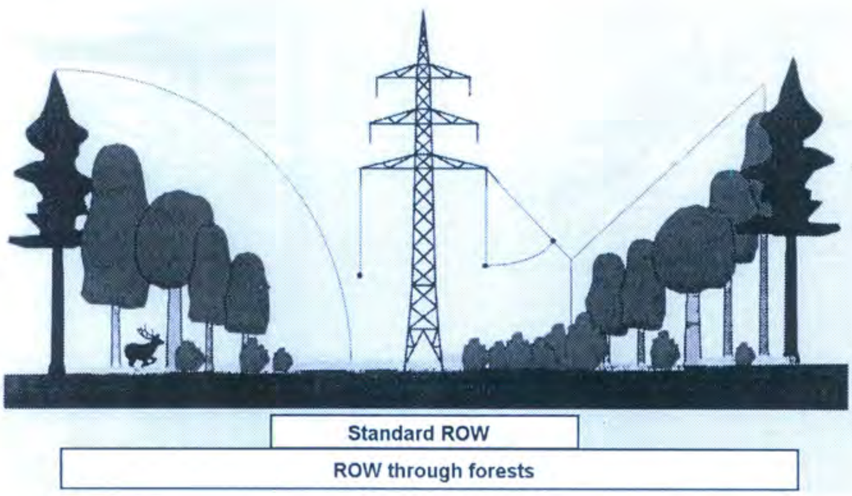



Fig. 1. ROW of high-voltage power lines (RWE Energie Aktiengesellschaft 1994).

## FRAMEWORKS OF RIGHTS-OF-WAY MANAGEMENT

### Legal aspects of planning and approval procedures

The planning and installation of transmission projects is regulated by certain national laws and regulations. Before a project is definitely realised, the energy supervisory authority has to examine the energy demand. Subsequent to this a public approval procedure starts, during which the approximate corridor of the line is determined. The detailed planning procedures need to meet the requirements of nature conservation. After finding the ecologically most compatible ROW, the final corridor will be authorised on condition that the disadvantageous effects of the power line on nature and the environment will be mitigated. Compensation can be achieved with conservation projects or payments. The last step of the public approval procedure is negotiating indemnification of the affected property owners. If no agreement is achieved, there will be the possibility of expropriation. Usually these approval procedures are very complex and may take very long time. As the public is becoming more and more sensitive to environmental problems, the establishment of power lines is often affected by great concerns. This is why approval procedures often take more than 10 years. But also the operation and maintenance of power lines have to meet high environmental standards.

### Technical requirements

In order to guarantee a secure and reliable energy transmission adequate protection zones are necessary. The design of such zones is calculated by certain standards and directions. The minimum clearance is regulated by standard OEVE-L 11§ 22,2 (Austria); the valid standard in Germany is DIN VDE 0210/12.85. The standard ROW for high-voltage lines is determined by specific parameters (span, design of the poles or towers, voltage level). Beside this a voltage dependent minimum value has to be considered to prevent a flashover between the energised conductor and buildings or vegetation. The definition of ROWs in forests, basically defined the same way as standard ROWs, has become necessary for power lines leading through or near by forests (Fig. 1). It has to be guaranteed that conductors and poles or towers are not exposed to danger caused by trees falling due to windfall, fire, snow or erosion. The necessary distance results from the maximum height of the trees of the adjoining forest stand. The width of the ROW depends on the maximum height of the trees and the voltage-level. The maintenance of ROW will be executed by the owners of the properties themselves, the utility staff or contractors.

### Ecological requirements

During the last decade, ecological planning of ROW has become more important. In this field several scientific studies have shown promising results regarding the ecological planning of high-voltage corridors (see, among others, Sachslehner and Schmalzer 1994; Killer, Ringler, and Heiland 1994). Most of these studies suggest that several successive years of clearcutting and tree-trimming on ROW can improve the ecological situation because such successive processes are rather rare in open cultivated landscapes as well as forested areas. From an ecological point of view, the following activities are recommended:

- selective advancement of small and low-growing plant species to minimise the effect of separating the ROW;
- developing vegetation which stabilises the edge of the forest;
- realisation of vegetation maintenance techniques appropriate for specific sections;
- no service in tree and shrub-free primary sites;
- preservation of natural ground reliefs;
- mowing, if necessary, at long-term intervals.

It has become an overall goal of utility companies to fulfill diverse ecological demands of the public. Most studies have shown that site-related ROW management techniques could minimise negative effects on nature and landscape. In some cases sections of ROW have been defined as nature reserves.

## REALISATION OF RIGHTS-OF-WAY MANAGEMENT

### Rights-of-way management in forested areas

The forests in central Europe have been affected by intensive human use for more than 1000 years. Accordingly, natural forests are rare nowadays. Central Europeans, especially Germans, Swiss and Austrians have a strong emotional attachment to the so-called "natural forests". This may explain why the environmental protection movement remains focused upon preservation of forests. Power companies have to respect this social attitude as they execute ROW control techniques.

In the course of time, all utility companies have turned away from complete clearcutting and the application of herbicides. They have developed new methods of ROW management using different spatial and temporal operations (Häusler, Röhrenbeck, and Uther 1994). Depending on topography and other site-related characteristics, this leads to the process shown in Fig. 2.

The main objective today is to optimize the ROW maintenance in the borders of its ecological, economic and technical framework (Uther and Janus 1996). These aspects should be taken into account in the same ratio if possible. One important step towards achieving this goal is support of slow-growing species with heights ending far below the lines. The aim of these measures is to develop a step structure across the corridor to the edge of the forest. If the edge of the forest is designed like this, formerly intensively controlled areas could be maintained with one-third of the effort previously required (Coch 1995). This decreases vegetation maintenance costs and ecologically improves the ROW. It also helps ensure the reliability of electrical systems by stabilising the adjoining forest stand.

The restructuring of vegetation systems has to be planned and realised continuously by long-term pro-

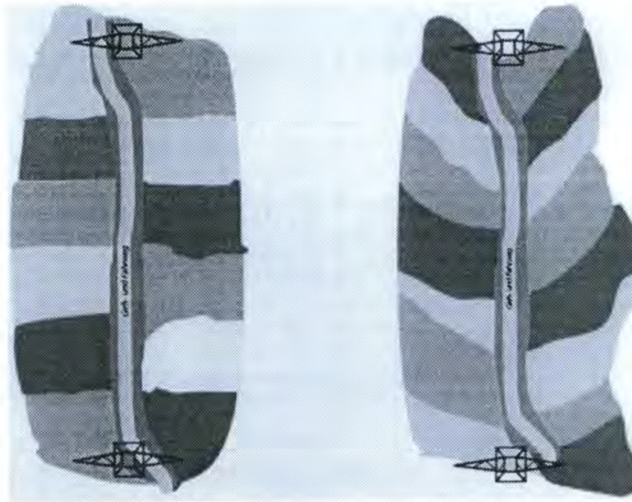


Fig. 2. Methods of ROW management using different spatial and temporal operations (RWE Energie Aktiengesellschaft 1995).

grams (Coch and Uther 1994). A biotope management planning procedure has been developed to formulate concrete goals and ensure their systematic realisation over the last years. Before planning activities can start the following basic information is required:

- extent and exact location of nature reserves (i.e. forest, water and soil of different categories)
- owner of the property
- ecological importance of this area
- registration and description of the ecological system

Based on this elementary information, a concept for future maintenance is developed. Besides meeting all technical requirements, a control technique for certain parts of the corridor is defined by determining the procedure, scale and interval. This process helps to ensure that, as a first step, each ROW is optimised according to its ecological possibilities. The final optimisation process depends on economic and safety perspectives. Corrective actions will be realised if needed. The different maintenance activities are recorded in operation maps (scale 1:2000) as shown in Fig. 3. In order to ensure the sustainability of the actions, the biotope management planning procedure is coordinated

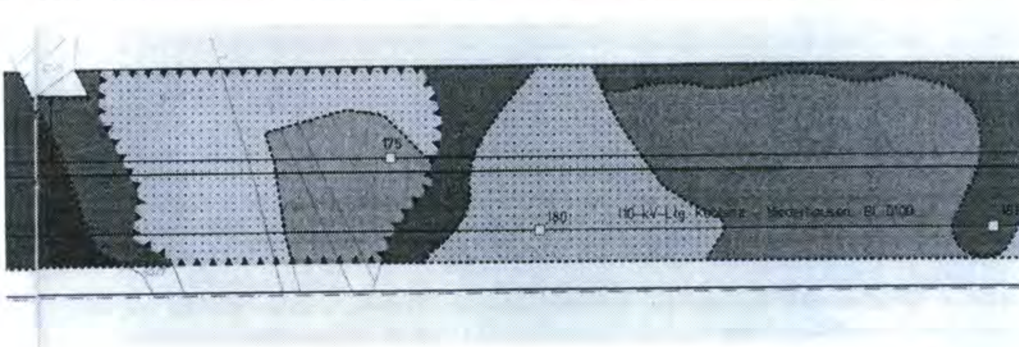


Fig. 3. Demonstration of measures in a ROW by scale and interval, according to the recorded biotope management planning procedure (RWE Energie Aktiengesellschaft 1996).

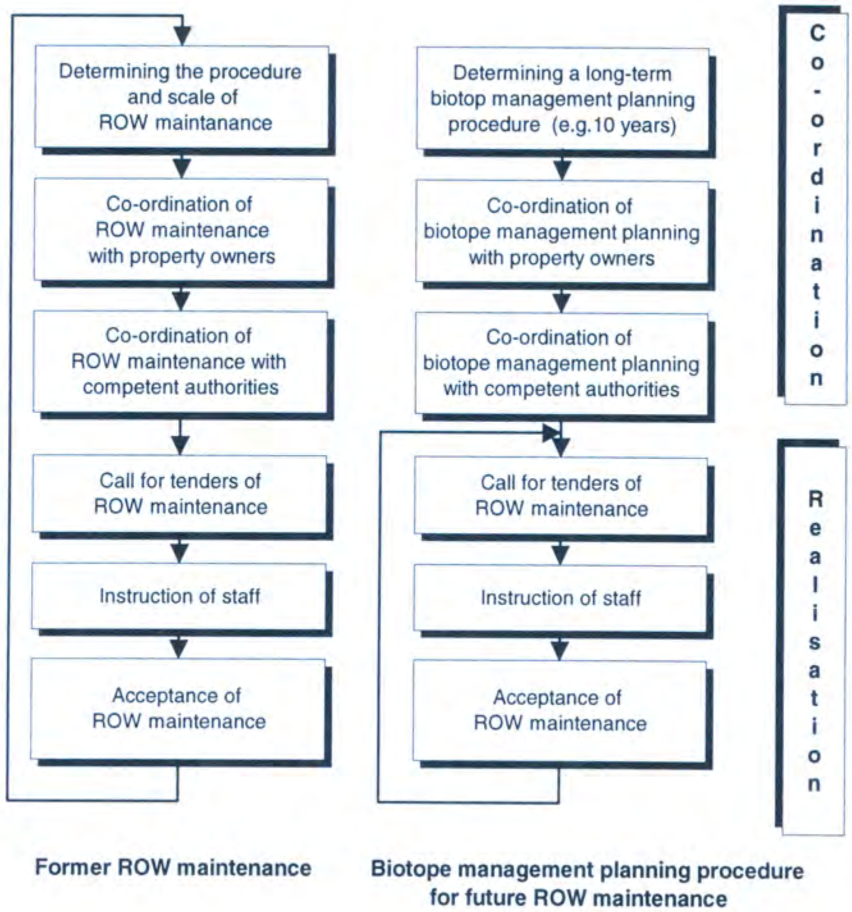



Fig. 4. Schematic procedure of ROW management. Improvement of efficiency by separating the coordination phase from the realisation phase.

by competent authorities, nature conservation organisations and property owners. Because of these actions, planning of the internal, entrepreneurial operations are simplified and improved by separating the coordination phase from the realisation phase, as shown in Fig. 4.

## ROW maintenance outside forests

The framework of ROW maintenance in civilised areas and in open cultivated landscape is different to that in forests, except for technical and legal handicaps. The ROW control techniques have to be changed because, in contrast to forested areas, a large number of isolated shrubs and trees on wayside, in fields, gardens and parks have to be taken care of (RWE Energie Aktiengesellschaft 1996). If maintenance of the lines becomes necessary and trees or high brushes have to be removed, most of the actions taking place are observed by attentive and critical citizens. In some cases landowners are also affected by separate local utility companies. Therefore it is essential that all action should be carried out with great respect to the sensibility of individual customers. The biotope management planning procedure, as performed in wooded areas, is not effective outside forests. To improve the maintenance procedure in these areas, *RWE Energie AG* has developed a database management system which documents the registration of hundreds of independent actions. The basic information, such as procedure of maintenance, landowner and nature preserve, is collected, documented and transferred to a land register data bank.

## Realisation of biotope management planning procedure

The physical vegetation control techniques are realised either by utility staff or contractors. In both cases it has to be ensured that all control techniques will be performed correctly, according to requirements of the competent authorities and internal entrepreneurial guidelines. The relevant knowledge, including modified theoretical background information and requirements by authorities, are transmitted by training. Also, practical introductions for maintaining will be carried out on the ROW. Each predefined step of action is followed by quality control measures, which are also useful for controlling and optimising costs of maintenance. Acquired information is also used to assist future planing activities.

## FUTURE ASPECTS

### Research project

In the light of the increasing importance of ecological ROW maintenance, the *Verbund (Vienna)*, *RWE Energie AG (Essen)* and *EVS AG (Stuttgart)* will start a common research project in 1997. Strategies and programs for an ecological and sustainable ROW management will be developed within five years, and because of the integrated approach, economic optimisation should also be achieved. The practical realisation of these new planning methods will take place on selected stripes representing different types of landscapes. Knowledge acquired in this project will be used for ecological planing of open spaces in substations. Within the scope of this research project the following objectives are considered.

- Elaborating principles for the ecological design of high-voltage corridors and the development of concepts for maintenance and arrangement of habitats on selected ROW:
  - planning of biotopes,
  - design of living space for birds, reptiles and insects,
  - design of net-shaped biotope structures.
- Development of methods and procedures to evaluate ecological and economic control techniques for existing and future high-voltage corridors
- Improvement of documentation systems (geographical information system, environmental information system)
- Development of specific guidelines for all different landscapes to ensure correct realisation of planned measures.
- Recommendations for owners for alternative land use.

### Environmental management systems (EMS) for high-voltage transmission networks

One of the most significant environmental issues facing industries today is the challenge of implementing EMS. There are now two leading standards for EMS. In 1993 the European Community initiated an environmental marketing instrument, which introduces the voluntary participation on the Eco-Management and Audit Scheme (Council Regulation 1993). In addition to this, there is also ISO 14001, a popular international standard (OENORM 1995).

The planning and design of transmission projects require a large amount of considerations by utility companies. Most of the criteria or problems that arise are related to environmental subjects. Therefore there is a need for implementation of a powerful instrument for controlling interdisciplinary activities. The following grouped list, according to an UNIPEDE study in 1993 (UNIPEDE 1993), points out the individual fields and their possible scope for EMS.

*Planning/approval procedures:*
- Approval procedures performed at the same time
- Implementing environmental matters in planning procedure
- Involving environmental groups and local communities at an early stage
- Consulting environmental and planning authorities before initiating the formal procedure
- Extensive information and integration of the general public
- Guide for impact studies

The general documentation of impacts caused by transmission networks is required by both standards. It could accelerate impact studies or environmental impact assessments. The establishment of documented operating procedures, which underlie a periodic improvement process, guarantees the early involvement of affected groups on appropriate level of communication. It also helps to avoid time-consuming serial procedures.

*Environmental matters:*
- Aesthetic towers or poles and equipment
- Visual presentation
- Research on electric and magnetic fields
- Vegetation management

Both standards require the economically viable application of the best available technology. The effective application of new visualisation tools will assist a company's attempts for a broad acceptance and help in the assessment of new power line routes. Collated and well-documented information on several independent research projects concerning the effects of electric and magnetic fields will augment communication with the public. With the installation of integrated vegetation management programs of rights-of-way, effective results at affordable costs with minimum impact on the environment can be achieved. Long-term vegetation management programs are also a good example for the required improvement of environmental performance.

*Technical improvements:*
- Use of compact lines
- Exact line routing considering landscape
- Increasing the capability of transmission network

The use of newly designed compact lines will contribute to the reduction of visual impact by tower heights and ROW. Special guidelines on line routing for different types of landscape, established and documented in the environmental management handbook, will make internal project management more effective.

*Professionalism:*
- Training sessions on environment for utility people and contractors
- Visual presentation

The implementation of EMS requires that all personnel whose work may significantly impact the environment will receive appropriate training. The establishment and maintenance of procedures will make its employees and members at each relevant function and level aware of the importance of conforming with the environmental policy and procedures in their roles and responsibilities.

*Policy-oriented:*
- Establishment of an environmental policy
- Inform and ensure a more active dialogue with the public

The environmental policy must ensure that it is appropriate to the nature, scale and environmental impacts of a utility's activities. It also includes a commitment to continual improvement and prevention of pollution (Verbund 1996). It is also the framework for setting and reviewing environmental objectives and should be available to the public. One major aspect is communication in the utility company itself. Requests by external interested parties regarding environmental aspects are very important and should be answered and documented. The EMS contains checking and corrective actions which ensure periodic evaluation and compliance with relevant environmental legislation and regulations.

The implementation of environmental management systems (EMS) will become of great importance for utility companies who design and operate high-voltage power lines. A certification and/or validation by standards is strongly recommended for the future (Draxler, Praxl, and Hofbauer 1996). Due to the present structure of the Eco-Management and Audit Scheme (EMAS-Regulation), no voluntary participation of transmission networks companies is possible. A new issue of EMAS is not expected before 1999. However, at present, any EC-member can include additional economic sectors by individual provisions (e.g. high-voltage power transmission). With respect to this situation, the implementation of environmental management systems and certification (according to ISO/DIS 14001) of network companies is assumed to be a reasonable policy for now. An agreement of EMAS and ISO relating to ISO-certified utilities may be expected in the future. Certified EMS should not be seen only as a voluntary marketing tool. Any implementation of EMSs based on a company-wide integration will strongly improve the internal processes and will reduce environmental costs in the future.

## CONCLUSION

Today the electric utility companies as *RWE Energie AG* and *Verbund* are endeavouring to develop new strategies for ROW maintenance that fulfill ecological and economic requirements. The proposed concept for a long-term oriented vegetation management program, performed without the application of herbicides, helps take into account the different interests of the competent authorities, property owners and the public. To improve ROW management further a research project will start in 1997. The integration of ROW management in a company-wide Environmental Management System, dealing with all environmental aspects belonging to high-voltage lines, is recommended for the future.

## ACKNOWLEDGMENTS

The authors would like to thank Mrs. Claudia Jürdens, *RWE Energie Aktiengesellschaft* for correcting the paper.

## REFERENCES

Coch, Th. and D. Uther. 1994. Biotopmanagement in walddurchquerenden Trassen von Hochspannungsfreileitungen. Naturschutz und Landschaftsplanung, 26 (3): 89–93.

Coch, Th. 1995. Waldrandpflege – Grundlagen und Konzepte . Neumann Verlag, Radebeul, Germany.

Council Regulation (EEC) (ed.) No 1836/93. 1993. Voluntary participation by companies in the industrial sector in a Community eco-management and audit scheme. Official Journal of the European Communities, L168: 1–18.

Draxler, R., G. Praxl and F. Hofbauer. 1996. The implementation of environmental management systems for high-voltage transmission networks. Paper presented at the 2nd Technical Sessions, Powerlines and the Environment, REE Red Electrica. Madrid, Spain, May 1996.

Häusler, Chr., G. Röhrenbeck and D. Uther. 1994. Pflegemaßnahmen in Leitungstrassen. Elektrizitätswirtschaft, 93 (23): 1395–1403.

Killer, G., A. Ringler, and S. Heiland. 1994. Lebensraumtyp Leitungstrassen; Landschaftspflegekonzept Bayern; Band II.16. Bayerische Akademie für Naturschutz und Landschaftspflege (ANL), Munich, Germany.

OENORM. 1995. EN ISO 14001 Environmental management systems — Specification with guidance for use (ISO/DIS 14001:1995-08). Österreichisches Normungsinstitut, Vienna, Austria.

RWE Energie Aktiengesellschaft. 1996. Biotopmanagement in walddurchquerenden Trassen. Essen, Germany.

RWE Energie Aktiengesellschaft. 1996. Trassenpflege in Gärten und Parkanlagen. Essen, Germany.

RWE Energie Aktiengesellschaft. 1994. Projektierung des Hoch- und Höchstspannungsnetzes. Essen, Germany.

RWE Energie Aktiengesellschaft. 1995. Richtlinie für Hochspannungsfreileitungen, Schutzstreifen. Essen, Germany.

Sachslehner, L. and A. Schmalzer. 1994. Ökologische Auswirkungen von Leitungsschneisen und Folgerungen für deren naturraumverträgliche Gestaltung und Pflege-Zwischenbericht. Verein für Ökologie und Umweltforschung, Vienna, Austria.

UNIPEDE. 1993. New Transmission Lines and Cables and Environment. Report presented at the UNIPEDE special workshop. Berlin, Germany.

Uther, D. and R. Janus. 1996. Natur- und Gewässerschutz. In Stand und Trends der Leitungstechnik. K.H. Weck, no 61, ETG Fachbericht, Berlin and Offenbach, Germany.

Verbund. 1996. Umweltbericht 1995, Vienna, Austria.

## *BIOGRAPHICAL SKETCHES*

***Reinhard Draxler***

*Graz University of Technology, Institute of High-Voltage Engineering, Inffeldgasse 18, A-8010 Graz, Austria*

Reinhard Draxler, Dipl.-Ing., studied electrical engineering from 1987 to 1994 at the University of Technology in Graz (Austria). Since 1995 he has been working on a research project at the Institute of High-Voltage Engineering at this University. The project deals with strategies for the implementation of quality and environmental management systems for high-voltage transmission networks.

***Dirk Uther***

*RWE Energie Aktiengesellschaft, Energy Transmission (E), Kruppstrasse 5, D-45128 Essen, Germany*

Dirk Uther, Ass. d. F., studied forestry and political economy in Bonn and Freiburg (Germany) from 1982 to 1987. Until 1987 he worked in the forest administration of the federal state Baden-Württemberg. Since 1990 he has been employed at RWE Energie Aktiengesellschaft Head Office in Essen. He belongs to the Central Division "Energy Transmission". As the representative for nature conservation, Dirk Uther's area of responsibility is the environmental management of the company's ROWs.

***Gerhard Praxl***

*Graz University of Technology, Institute of High-Voltage Engineering, Inffeldgasse 18, A-8010 Graz, Austria*

Gerhard Praxl, Prof. Dr., Graz University of Technology (Austria), Institute of High-Voltage Engineering, Quality and Environmental Management. Member CIGRE, IEEE, OEGE/OEVE. Research and lectures in quality and environmental management, reliability engineering.

***Franz Hofbauer***

*Österreichische Elektrizitätswirtschafts AG (Verbund), Am Hof 6A, A-1010 Vienna, Austria*

Franz Hofbauer, Dipl.-Ing. Dr. Since 1981 he has been employed at Österrreichische Elektrizitätswirtschafts AG (Verbund) in Vienna. From 1994 to 1995 he was head of the Electrical and Mechanical Engineering department (Verbund-Engineering). In 1996 he became head of a division at Verbund and is now responsible for power system control.

# Trial Plantings of Perennial Plants on Electric Transmission Line ROWS in North Louisiana

**Kenneth W. Farrish, Charles E. Rowell, and James M. Dyer**

Trial plantings of small trees, shrubs and low growing perennial herbaceous plants were made on three electric transmission rights-of-ways (ROWs) in north Louisiana. The purpose of the plantings was to ascertain the opportunities and constraints from using planted perennial plants to both improve ROW aesthetics and wildlife values, and produce a stable vegetation community requiring less maintenance. The goal of the project was to establish selected species in three height growth zones to achieve the desired bowl-shaped vegetation canopy. Small tree species were planted on the ROW edge next to the adjacent forest. Shrub species were planted in a zone between the small trees and the area directly under the transmission lines. Perennial herbaceous species were planted under the transmission lines. Small tree survival was good over three growing seasons of the study. However, growth of the trees was disappointing. Above and below ground competition from the adjacent large forest trees appeared to restrict growth of the planted trees. The shrub species made better growth, probably because of their greater distance from the forest. Wax myrtle and Lespediza did particularly well. Survival, however, after three growing seasons was mixed for the shrub species. The perennial herbaceous plantings were completely unsuccessful. The project demonstrated that while aesthetics of the ROWs may be enhanced with group plantings of small trees and shrubs, establishing the desired bowl-shaped vegetation canopy using plantings in forested landscapes of the region will be difficult to achieve at reasonable cost.

*Keywords*: Rights-of-way plantings, perennials, aesthetics, vegetation management, trees, shrubs, group plantings, wildlife values

## INTRODUCTION

An approach to ROW vegetation management that has been researched, although to a lesser extent than management of native vegetation, has been the conversion of all, or parts, of ROWs to artificially established plant communities. Most of these efforts have been directed toward the establishment of plant communities that produce habitat or food for various wildlife species (Arner, Cliburn, Thomas, and Manner 1976; DeWilde 1976; Gillespie 1978; Huntley, Arner, and Arner 1979; Hutnik, Bramble, and Byrnes 1987). Use by wildlife of such areas has been documented, but maintaining such areas for long periods of time has proven difficult because of the encroachment of undesirable native plant species, particularly hardwood tree species (Arner 1977; Galvin, Hoover, and Avery 1979, Malefyt and de Waal 1982).

Another increasingly important concern of ROW managers is to change the public perception that these corridors are unattractive. One way to accomplish this is by establishing plant species that are aesthetically pleasing. By planting native plant species that have attractive flowers or foliage, the aesthetics of ROWs can be enhanced (Anton and Bunnell, 1976; Horsley 1983). The use of aesthetically pleasing native plants on ROWs has been researched somewhat, but primarily on highway or railroad ROWs (Ahern 1987; Clemence 1977; Gouveia 1987; Rosenthal 1976).

This project was conducted to explore the potential of establishing planted perennial plants on electric transmission ROWs to form a low maintenance, stable, bowl-shaped plant community of superior aesthetic appeal that also favors wildlife values.

## OBJECTIVES

The overall goal of this study was to determine the feasibility of using plantings of perennial vegetation to establish the desired bowl-shaped vegetation canopy on electric transmission ROWs, while also offering enhanced wildlife and aesthetic values. Specific objectives were: (1) to establish a trial grouping of perennial plants that enhance both aesthetics and wildlife values with little required maintenance; (2) to horizontally stratify the planted species within the ROW according to height growth potential and thereby establish the desired bowl-shaped vegetation community; and (3) to determine if blade plowing to control undesirable woody vegetation would enhance survival and growth of the planted perennial plants.

## METHODS

### Study area

Three study areas were selected in north-central Louisiana (near Dubach, Simsboro, and Vienna, LA) on 30 m (100 ft) wide 150 kV electric transmission ROWs. The study areas were selected for similar soil and forest type characteristics that represent the region's upland mixed pine/hardwood forest ecotype.

Plant species for the study were selected according to the following criteria:

1. Aesthetically pleasing plants that are also beneficial to wildlife.
2. Plants that are primarily native, or naturalized, to the region so as to avoid problems associated with exotic species.
3. Plants that have a variety of flowering and fruiting times.
4. Plants that are drought tolerant and aggressive growers and seeders.
5. Plants that need little or no maintenance and only minimal site preparation.

In an attempt to develop the desired bowl shape across the horizontal plane of the 30 m (100 ft) wide ROW, each 15 × 15 m (50 × 50 ft) treatment plot was divided into approximately equal 5 m (16 ft) size segments called zones. Zone 1 was that 5 m portion of the treatment plot closest to the forest edge. Zone 1 plantings consisted of small tree species capable of 3.6–6 m (12–20 ft) in height growth. These plants were: (1) parsley hawthorne (*Craetagus marshallii*); (2) deciduous holly (*Ilex decidua*); (3) redbud (*Cercis canadensis*); (4) winged sumac (*Rhus copallina*); and (5) Mexican plum (*Prunus mexicana*). Nursery-raised planting stock was used.

Zone 2 area was midway between the ROW center and the adjoining forest edge, 5–10 m from the ROW edge (16–32 ft). This zone was planted with small shrub species capable of height growth between 1.2 and 3.6 m (4 and 12 ft). These plants were: (1) French mulberry (*Callicarpa americana*); (2) bicolor lespedeza (*Lespedeza bicolor*); (3) blueberry (*Vaccinium elliottii*); (4) yucca (*Yucca aloefolia*); and (5) waxmyrtle (*Myrica cerifera*). Nursery-raised planting stock was used.

Zone 3 was the area located beneath the conductors in the ROW, 10–15 m (32–50 ft). This zone was planted with herbaceous plants capable of growing no more than 1.2–2.5 m (4–8 ft) in height. These plants were: (1) sericea lespedeza (*Lespedeza cuneata*); (2) goldenrod (*Solidago* sp.); (3) aster (*Aster* sp.); (4) black-eyed susan (*Rudbeckia hirta*); and (5) vervain (*Verbena rigida*). The soils were disked before planting and the seed was applied with a hand spreader. No lime or fertilizer amendments were applied to any of the plots. Evaluation of plant establishment on the study plots was made after one, two and three growing seasons. However, only the third year data is reported in this paper. Planted trees were permanently marked when planted and measured for ground-line diameter and total height. Shrubs were measured for crown diameter and total height. At the remeasurement periods, each planted shrub and tree was identified and remeasured for the listed parameters. Herbaceous plantings (Zone 3) were evaluated at the same time using a random microplot 1.2 × 1.2 m (4 × 4 ft) sampling technique.

## RESULTS AND DISCUSSION

### Small tree species (Zone 1)

Survival of planted small trees after three growing seasons at the Dubach and Vienna sites was generally good (Table 1). However, new powerline construction activities at the Simsboro site destroyed many of the planted trees at that location. Consequently, that site is excluded from further discussion of the tree plantings. Some mortality also occurred at the Dubach and Vienna sites during 1995, probably due in part to the severe drought of that summer. Nevertheless, survival after three growing seasons of parsley hawthorne and Mexican plum was as high as 89 and 75%, respectively, on control plots (no blade plowing). Even winged sumac, which had the poorest overall survival, still had 67% of the planted seedlings alive after three growing seasons.

Unexpectedly, survival of planted trees was generally somewhat better, with the exception of Mexican plum, on the control plots than on the blade plow treatment plots.

**Table 1. Survival of planted small trees after three growing seasons at Dubach and Vienna**

| Species | Control (%) | Blade plow (%) |
|---|---|---|
| Deciduous holly | 72 | 55 |
| Parsley hawthorne | 89 | 75 |
| Redbud | 72 | 55 |
| Winged sumac | 67 | 61 |
| Mexican plum | 75 | 78 |

**Table 2. Height and diameter after three growing seasons of planted small trees at Dubach and Vienna**

| Species | Height (cm) | | Diameter (mm) | |
|---|---|---|---|---|
| | Control | Blade plow | Control | Blade plow |
| Deciduous holly | 97 | 114 | 10 | 12 |
| Parsley hawthorne | 74 | 88 | 10 | 12 |
| Redbud | 72 | 73 | 9 | 11 |
| Winged sumac | 89 | 81 | 9 | 10 |
| Mexican plum | 85 | 80 | 8 | 9 |

**Table 3. Survival (%) of planted shrubs after three growing seasons at Dubach and Vienna**

| Species | Control (%) | Blade plow (%) |
|---|---|---|
| Blueberry | 60 | 45 |
| French mulberry | 75 | 65 |
| Lespediza | 43 | 65 |
| Wax myrtle | 48 | 70 |
| Yucca | 67 | 62 |

**Table 4. Height and diameter of planted shrubs at Dubach and Vienna**

| Species | Height (cm) | | Crown diam. (cm) | |
|---|---|---|---|---|
| | Control | Blade plow | Control | Blade plow |
| Blueberry | 83 | 78 | 43 | 35 |
| French mulberry | 75 | 82 | 49 | 49 |
| Lespediza | 189 | 210 | 93 | 107 |
| Wax myrtle | 131 | 142 | 87 | 94 |
| Yucca | 45 | 50 | 49 | 52 |

This is in spite of the fact that competition from other woody species, such as sweetgum (*Liquidambar styraciflua*), was greatly reduced on the blade plow plots.

Planted trees still averaged less than one meter in height and about 10 mm in groundline diameter after three growing seasons (Table 2). The small amount of growth in the planted trees may be due to the fact that they were planted close to the edge of the off ROW forest. It was apparent that above and below ground competition from adjacent forest vegetation reduced growth of even natural vegetation, such as sweetgum, in this location. This forest edge competition may present an obstacle to the establishment of the desired bowl-shaped vegetation canopy on ROWs using plantings. There was no apparent relationship between planted tree size after three growing seasons and the blade plow treatment.

### Planted shrubs (Zone 2)

Survival of planted shrubs over three growing seasons was generally somewhat poorer than that for the small trees (Table 3). Some mortality occurred during the drought of 1995. For example, survival of blueberry declined to 45% on the blade plow plots from 62% the previous year.

Wax myrtle and lespediza shrubs grew somewhat better on the blade plow treatment (Table 4). However, the other shrub species did not respond with increased growth in the blade plow plots. The planted shrubs generally grew to be as tall or taller than the planted trees of Zone 1. This may be because the shrub zone was further from the intense competition of the forest edge discussed earlier. Surviving wax myrtle and lespediza after three years had particularly developed into healthy specimens, averaging 130 and 210 cm in height, with crown diameters of 90–110 cm, respectively. Yucca on the other hand, the smallest of the shrub species, attained an average height of only 50 cm.

### Perennial herbaceous plants (Zone 3)

Establishment of seeded, perennial, herbaceous plants (Zone 3) was unsuccessful. The only planted species that developed in the plots was black-eyed susan, and it was growing wild in the study area already. Establishment of perennial plants from seed is often difficult. More work would be necessary to develop successful establishment techniques for these herbaceous plants. Species trials and development of planting techniques for the region are needed.

## CONCLUSIONS

Small tree survival was good over the four years of the study. However, growth of the trees was disappointing. Above and below ground competition from the adjacent large forest trees appeared to restrict growth of the planted trees. The planted shrubs made better growth, probably because of their greater distance from the forest. Wax myrtle and lespediza did particularly well. Survival after four years was mixed for the five shrub species. The perennial herbaceous plantings were completely unsuccessful. The project demonstrated that while aesthetics of the ROWs may be enhanced with group plantings of small trees and shrubs, achievement of the desired bowl-shaped vegetation canopy will be difficult to achieve at reasonable cost using plantings.

## ACKNOWLEDGEMENTS

This research was funded by Entergy Corporation. Special appreciation is extended to Mr. James R. (Randy) Williams who offered the insight and support that fostered this work.

## REFERENCES

Ahern, J.F. 1987. The establishment and maintenance of wildflowers and native woody plants in the highway landscape. In: Proceedings of the Fourth International Symposium on Environmental Concerns in Rights-of-Way Management. Dept. of Forest and Nat. Res., Purdue Univ., West Lafayette, Indiana.

Anton, W.F. and Bunnell, J.L. 1976. Environmental protection guidelines for constructing projects. Journal of the American Water Works Association, 68(12): 643–646.

Arner, D.H. 1977. Topical briefs: Fish and wildlife resources and electric power generation, No. 2. Transmission Line Rights-Of-Way Management. U.S. Fish and Wildlife Service, Rpt. No. FWS/OBS-76/20.2, NTIS, No. PB-266167. 18 pp.

Arner, D.H., L.E. Cliburn, D.R. Thomas, and J.D. Manner. 1976. The use of fire, fertilizer and seed for rights-of-way maintenance in the Southwestern United States. In: Proceedings if the First International Symposium on Environmental Concerns in Rights-of-Way Management. pp. 156–165.

Clemence, S. 1977. Creative utility right-of-way management. Public Power, 35: 5, 55–57.

DeWilde, R.C. 1976. Innovations in right-of-way seeding. (Aerial application of fertilizers, growth substances and seeds to reclamation areas). Journal of Arboriculture, 2(7): 131–132.

Galvin, M., K.D. Hoover, and M.L. Avery. 1979. Management of transmission line rights-of-way for fish and wildlife, Volume 2: Eastern United States. U.S. Fish and Wildlife Ser., Report No. FWS/OBS-79/22-2, 368 pp.

Gillespie, E.D. 1978. Cover crops as a control for woody growth on electrical transmission rights-of-way. Reclamation and Revegetation, 1(1): 31–33.

Gouveia, C.H. 1987. Native plants: Cornerstone of low maintenance right-of-way management. In: Proceedings of the Fourth Interational Symposium on Environmental Concerns in Rights-of-Way Management. Dept. of For. and Nat. Res., Purdue Univ., West Lafayette, Indiana.

Horsley, V.D. 1983. Restoration Following Transmission Line Construction. Canadian Land Reclamation 8th Annual Meeting, Univ. of Waterloo, Ontario, Canada. Trans. Env. Dept., Ontario Hydro, Ontario, Canada.

Huntley, J.C., D.H. Arner, and D. Arner. 1979. Effect of Utility Right-of-Way Maintenance upon Game Food Plants. Proceedings of the Second International Symposium on Environmental Concerns in Rights-of-Way Management. pp. 31.1–31.13.

Hutnik, R.J., W.C. Bramble, and W.R. Byrnes. 1987. Seedbank contents on an electric transmission right-of-way. In: Proceedings of the Fourth International Symposium on Environmental Concerns in Rights-of-Way Management. Dept. of For. and Nat. Res., Purdue Univ., West Lafayette, Indiana.

Malefyt, J. and J. de Waal. 1982. Effect of vegetation management on bird populations along electric transmission rights-of-way. Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University, Starkville, MS. pp. 570–580.

Rosenthal, R.N. 1976. Vegetative Cover for Highway Rights-Of-Way. Fed. Hwy. Admin., Olympia, Washington. Report. no. FHWA/WA-76/14.2, 33 pp.

## *BIOGRAPHICAL SKETCHES*

***Kenneth W. Farrish***

*Arthur Temple College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962, USA*

Kenneth W. Farrish is an Associate Professor of Forest Soils in the Arthur Temple College of Forestry, Stephen F. Austin State University in Nacogdoches, Texas. Previously, he was a faculty member in the School of Forestry, Louisiana Tech University. He received his B.S. and M.S. degrees in Forestry from Michigan Technological University, and the Ph.D. from the University of Minnesota.

***Charles E. Rowell***

*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

Charles E. Rowell is an Associate Professor of Forest Ecology and Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. in Political Science and M.S. in Forestry from Mississippi State University, and the Ph.D. in Forestry from the University of Kentucky.

***James M. Dyer***

*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

James M. Dyer is a Professor of Wildlife Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. and M.S. degrees in Wildlife Management from Oklahoma State University, and the Ph.D. from Louisiana State University.

# Nearly Two Decades of Integrated Vegetation Management on Electric Transmission Rights-of-Ways

**Kenneth E. Finch and Scott D. Shupe**

One Northeast utility has routinely used herbicides to control vegetation on its electric transmission rights-of-ways since the 1950s, including extensive helicopter application during the 1960s and 70s. This utility has reduced its herbicide usage rates from more than six gallons of concentrate per acre when helicopter spraying, to less than one gallon per acre today following Integrated Vegetation Management (IVM) strategies. IVM is that component of Integrated Pest Management (IPM) which balances the use of cultural, biological, mechanical and chemical procedures for controlling undesirable vegetation on rights-of-ways. The IVM strategies employed include a 7–8 year cyclical treatment program, site specific vegetation inventories, prescription programming, regular crew training and familiarization programs, and a recent "partnership" with vegetation management contractors. In addition to effective vegetation control, the IVM methodology has provided reduced regulatory conflicts, greater public acceptance, enhanced wildlife habitat and right-of-way aesthetics, reduced worker exposure and significant cost savings.

*Keywords*: Reliable electric service, cost effective, long-range program, Integrated Vegetation Management (IVM), desirable and undesirable vegetation, selective treatment, herbicide use reduction

## INTRODUCTION

This paper shares the evolution of right-of-way (ROW) management at Niagara Mohawk Power Corporation (NMPC), and especially the development and implementation of Integrated Vegetation Management (IVM) strategies over the last twenty years. NMPC was formed by the merger of several smaller utilities in 1950, providing service today to 1,500,000 electric and 500,000 gas customers across 24,000 square miles of upstate New York. Annual electric sales of 37,684 million kW, and gas sales of 224,817 thousand decatherms, combine to give a total revenue of $4.2 billion.

Niagara Mohawk hired its first professional System Forester to oversee vegetation management in 1962, as well as the first professional Forestry Supervisor to administer programs in the Capital District. Additional foresters were hired in the early 1970s, as environmental issues regarding the siting and construction of new transmission projects moved to the forefront. Division Forester positions were created in 1977, to develop and implement vegetation maintenance programs in the Eastern, Central and Western Divisions. The Divisional positions were expanded into eight Regional Forester positions in 1984. Today, the program includes 11 first line Forestry Supervisors and six Forestry Superintendents on Regional staffs; and three Environmental Foresters, a Secretary and the Manager of System Forestry on System staff. The Regional/System Forestry Department is responsible for all vegetation management activities at NMPC, including both maintenance and new construction. This team is supported by additional staff within the Environmental Affairs Department for permitting, licensing, research and outreach matters.

NMPC's vegetation maintenance program consists of:

- approximately 11,200 km (7,000 miles) of transmission right-of-way,
- 59,200 km (37,000 miles) of primary distribution circuits,
- 960 km (600 miles) of gas right-of-way,
- and bare ground application to more than 2,000 substations, pole yards, and gas regulator sites.

In 1996, the total vegetation management budget, including maintenance and capital, exceeded $25,000,000.

**Table 1. Transmission right-of-way management program (brush acres by voltage class)**

| | EHV Transmission 230, 345 kV | Transmission 69, 115 kV | Sub transmission 23, 34.5, 46 kV | Total |
|---|---|---|---|---|
| Capital | 4,410.1 | 2,718.2 | 1,131.9 | 8,260.2 |
| Northeast | 1,269.3 | 3,441.7 | 1,734.5 | 6,445.5 |
| Mohawk | 1,973.2 | 1,243.2 | 1,006.8 | 4,223.2 |
| Central | 3,243.7 | 3,048.7 | 1,705.0 | 7,997.4 |
| Northern | 800.6 | 4,138.5 | 2,769.5 | 7,708.6 |
| Genesee | 0.0 | 2,173.8 | 1,358.6 | 3,532.4 |
| Frontier | 1,014.8 | 1,185.7 | 293.7 | 2,494.2 |
| Southwest | 1,794.5 | 2,189.5 | 1,432.7 | 5,416.7 |
| System | 14,506.2<br>31% | 20,139.3<br>44% | 11,432.7<br>25% | 46,078.2 |

Table 1 identifies the total brush acres managed under the electric transmission right-of-way management program. The extra high voltage (EHV) transmission category includes ROWs of 45.7–152.4 m (150–500 ft) in width. NMPC's normal transmission lines are 115 kilovolts (kV), with a few 69 kV circuits, generally as ROWs 100 ft wide. Unlike many utilities, NMPC has an significant portion of its transmission system in subtransmission voltages of 23, 34.5 and 46 kV. These lines are maintained 15.2 m (50 ft) in width in residential and agricultural areas, and 22.9 (75 ft) wide in and around the forested areas of the Adirondack mountains.

## HISTORIC PERSPECTIVE

Table 2 chronicles key points in the development of the NMPC transmission right-of-way management program. A brief overview will help understand the evolution from broadcast to integrated strategies, from reactive to cyclical maintenance, from forestry "advisors" to program managers. This understanding will help define the program's successes in reducing herbicide usage and treatment costs. As our industry becomes more competitive and more customer driven, cost and pesticide reduction strategies will become the cornerstones of the successful programs. The concepts will become essential to secure continued support from senior management.

At the time NMPC was formed in 1950, right-of-way maintenance was primarily hand cutting by line crews during the winter, or non-construction season. This "filler" work was non cyclic, and targeted toward lines with outage problems. The coppice which resulted from hand clearing included fast growing hardwoods, such as maple, ash, poplar, black cherry, and birch.

Ammate herbicides were introduced for vegetation control programs in 1951. Ammate was a soluble crystal which dissolved in water for foliar application, or could be applied as crystals or paste directly to the cut stump. As a contact herbicide it provided top kill, but did not effectively translocate for root control Also, Ammate products were highly corrosive to application equipment.

Test plots with phenoxy herbicides were applied in 1953, with 2,4-D and 2,4,5-T introduced to the spray program in 1956. High volume ground foliar applications, using specialized contract crews became the primary treatment method. Specifications required "treatment of all woody brush which did not fall with the frost". Volatility and drift problems led to prohibitions on use in several counties in western New York were grape vineyards are common. As a result, Ammate treatments continued in these areas until 1984.

The phenoxy herbicides translocated, providing effective root control of nearly all species, except ash. The introduction of Tordon products in 1966 enabled the development of tank mixes to control a broader spectrum of species, including ash. The development of microfoil boom technology in the early 1960s led to the adoption of helicopter treatment as the preferred method through the early 1970s.

In 1973, the energy crisis and Con Edison's failure to declare a dividend created an enormous ripple effect throughout New York. Within months, NMPC's entire contract vegetation maintenance budget was eliminated, and contractors were laid off. Routine maintenance activities would not resume until 1976, and deferrals became the norm. It took a major tree caused outage on two separate 345 kV circuits, carrying power from the Nine Mile Point nuclear facility to get us back into the vegetation management business. This occurred in early summer, 1976.

Contracts were immediately let to treat 2,000 brush acres on our bulk and critical transmission circuits. Ninety percent (90%) of the work would be completed aerially. Contract applicators were allowed to helicopter treat from station to station, with instructions to establish "appropriate" shut off zones adjacent to agricultural fields, sensitive stream and river crossings, and residential areas.

**Table 2. Time line of ROW management events at Niagara Mohawk**

| | |
|---|---|
| 1950 | Niagara Mohawk formed |
| 1951 | Ammate herbicides first used |
| 1953 | Test plots with 2,4,5-T |
| 1955 | |
| 1956 | 2,4-D & 2,4,5-T herbicides introduced in program |
| 1960 | |
| 1962 | First professional foresters hired |
| 1965 | |
| 1966 | Tordon products introduced |
| 1970 | |
| 1972 | Article VII law – require environmental assessment and selective clear for new ROWs |
| 1973 | Con Ed declared no dividend due to oil embargo |
| 1974 | Loss of entire tree maintenance program |
| 1975 | |
| 1976 | Loss of 9 Mile nuclear plants due to trees, 2000 acres of helicopter spraying – 90% |
| 1977 | Garlon test plots, Division foresters hired, ROW inventories introduced, PSC helicopter show cause order, long-range ROW plans |
| First cycle: | |
| 1979 | 2,4,5-T banned by EPA, Garlon introduced |
| 1980 | Long-range ROW Plan approved, inventories computerized |
| 1982 | Last helicopter work |
| 1984 | Round up test plots |
| 1985 | Roundup herbicide introduced |
| Second cycle: | |
| 1987 | Accord/Arsenal tanks mixes introduced |
| 1990 | |
| 1991 | Compadre introduced |
| Third cycle: | |
| 1992 | Low volume and modified low volume foliar introduced, very light density created |
| 1993 | Handheld computers introduced for inventories |
| 1995 | "Partnership" with vegetation maintenance contractors |
| 2000 | |

However, there were cost pressures to minimize expensive ground methods, since we were only treating 2,000 acres of tens of thousands of acres needing attention. Numerous complaints and lawsuits followed. The public outcry drew attention from our state regulators, resulting in the issuance of a "show cause" order from the N.Y.S. Public Service Commission (PSC) on 20 December 1977.

The concept of selective clearing and maintenance strategies had been introduced to new transmission facilities in 1972, with the enactment of Article VII of N.Y.S. Public Service law. The PSC environmental staff seized this opportunity to expand its regulatory oversight role to existing ROW's. Through the "show cause" order the PSC required us to justify future use of helicopter spraying, and directed us to develop and submit for approval a "Systemwide Long Range ROW Management Plan". This plan must encompass all electric transmission ROW's, incorporating new selective management ideas supported by PSC environmental staff.

To accomplish these objectives NMPC began to centralize its vegetation management programs under the System Forester in 1977. Division Foresters positions were created in each of the three divisions by promoting foresters who had been working on new transmission projects. Functional control of vegetation management budgets was placed under the System Forester in 1978.

In those days, Integrated Vegetation Management was known as "selective" management. The current success of IVM was built on common sense and simple management principles:

1. Our regulators and the public might accept limited use of helicopter, but only to establish initial control in high density, non-sensitive areas; future maintenance would require more "selective" ground methods.
2. The program needed to be cyclical, treating tall growing "undesirable" vegetation before invading the wire security zone and causing outages.
3. It did not make sense to spray or hand cut low growing "desirable" vegetation which could never grow into the conductors. Fostering these desirable species would further provide wildlife food and cover.

In formulating the long-range management program and procedures, the foresters operated from a basic premise that herbicides are essential to achieve root control of undesirable tall growing vegetation. Without successful root control, the hardwood species native to the Northeast would rapidly out compete and outgrow all other vegetation in their race to the conductor.

They first turned to the work of Bramble and Byrnes in Pennsylvania. Their research, beginning in the early 1950s, documented the establishment of a mosaic of plant successional stages, using broadcast foliar, selective stem foliar, and basal herbicide methods. Following initial clearing, the treatments resulted in ROW conversions to low growing species, such as blackberry, bracken fern, blueberry, golden rod and grasses, which formed dense sod like, root zones. The treatments also sustained a vegetative species composition far less mature than the adjacent forest, that tended to resist reinvasion by tree species. This diverse mosaic also increased wildlife richness, numbers and usage when compared to adjacent forested areas.

In the early 1970s, Egler's theories concerning the competitiveness of shrub species was also gaining recognition on New York. The theory provided that certain shrub communities were stable over long periods of time, providing competition for and exclusion of taller growing hardwoods. The concepts had especially gained support within the Office of Environmental Planning at the PSC. Some of this seemed contrary to conventional teaching that shrub communities are early "successional" stages which naturally prepare the site for the next higher stage, the pioneer tree species and eventually the climax forest species.

Could we combine the effectiveness of herbicides to provide root control and prevent regrowth of unwanted species, with the resistance to reseeding described by Bramble and Byrnes, and still capture some of the shrub competitiveness espoused by Egler? Could we demonstrate cost savings and effectiveness as well? If we could, may be we could capitalize on the best of all worlds. Still, shrub retention was driven as much by economics as "environmentalism". Why spend time and money to treat something that would never grow into the lines?

## LONG RANGE RIGHT-OF-WAY MANAGEMENT PLANNING

Rudimentary inventories began in 1977, and were formalized into the hand inventory systems in 1978. The draft "Long Range Right-of-way Management Plan" required earlier, was prepared and submitted to the PSC for approval in May, 1978.

Inventory procedures require a trained forester to field review each ROW prior to treatment, identifying land use and vegetation conditions. Based on land use patterns, vegetation heights and densities, as well as environmental and public sensitivities, a specific treatment method is prescribed for each site. Ideally, this inventory occurs prior to bidding the coming years work, and serves to quantify brush heights and densities, by treatment method for the contractors as well. Each site is described to the nearest quarter span, to help crews locate scheduled work. Sites are also mapped on the transmission plan and profile drawings. The crews find the maps helpful in identifying odd shaped sites, such as a stream which wanders across the ROW, a garden in the corner of a stumptreat site, or a surface well within the ROW.

The land use and density classification system adopted in 1978 has remained virtually unchanged to this day, with the exception of a "very light" classification that was introduced in 1993 for undesirable, tall growing species. It includes:

Land use codes:
- 1000 streams
- 2000 wetlands
- 3000 highways, roads
- 4000 commercial, industrial, parks
- 5000 residential, seasonal
- 6000 active agricultural fields
- 7000 pasture lands
- 8000 brush lands
- 9000 woods (either side)

Undesirable species heights:
- 000 no height
- 100 small
- 200 medium
- 300 tall

Undesirable species density:
- 00 no undesirable species
- 10 very light (<100 stems/acre) (added in 1993)
- 20 light (0–30% cover)
- 30 medium (30–65% cover)
- 40 heavy (65–100% cover)

Desirable species density:
- 0 no desirable species
- 1 light (0–30%)
- 2 medium (30–65%)
- 3 heavy (65–100%)

In 1980, we computerized the field inventory system. This allowed summarizing the scheduled work, by acre, by density class, and by technique. It also allowed us to print a ticket for each site, which crews then used to report and track completions, chemical usage and costs. Computerization further enabled us to summarize and report undesirable species densities for future comparisons. In 1982, the program was modified to enable summary reporting and tracking of costs and herbicide usage per acre, by technique.

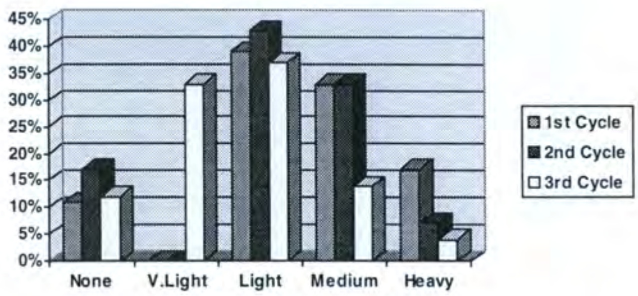
In 1992, the program was rewritten to adopt hand-held computer technology, streamlining the data entry process, and eliminating up to three months of data entry time. This also expedited our bid process. Over time, our contractors have become dependent upon these acres and density summaries for bid preparation. Site cards were eliminated to streamline field reporting and replaced with an inventory printout with space to enter completion date and herbicide amounts.

Selective maintenance on a cyclical program officially began in 1978, with all ROW's completed eight years later, in 1985. The second cycle extended seven years, from 1986 to 1992. By the end of the second cycle, significant shifts in undesirable species density were being observed, with a 10% reduction in heavy density sites, when compared to the first cycle (Graph 1). In addition, there appeared to be a noticeable increase in sites with very light densities. We believe most of the density reductions are occurring in foliar treatment sites. In order to better track this conversion to lighter undesirable densities, a "very light" category was added in 1993. The third cycle is an eight year cycle, extending from 1993 to 2000. The third cycle statistics reflect year to date inventories and costs through 1996. Herbicide reports will not be complete until 31 March 1997. As a result, herbicide usage trends are through 1995.

## UNDESIRABLE BRUSH DENSITIES

Graph 1 identifies the cycle-to-cycle shift in undesirable brush densities. During the first cycle, 50% of all treated acres were medium to heavy density, while only 18% of the acreage have the higher densities today. Half-way through the third cycle, 70% of the sites are either very light (33%) or light (37%). This is a significant shift in undesirable densities, which subsequently translates to reduced costs. It should be noted that more than 4,500 acres of new transmission were constructed during the first cycle, which were included in the cyclical maintenance program during the second cycle. This may account for the somewhat higher densities still reported in that cycle.

These reductions in undesirable densities are consistent with the results found in a separate research project undertaken by NMPC on its Volney–Marcy 345 kV right-of-way between 1983 and 1991. That 1992 report evaluates both treatment efficacy and cost to determine cost effectiveness by technique. It shows cycle-to-cycle reductions undesirable stem densities, the endurance of desirable stem counts, marked reductions in herbicide volumes, and the generally greater performance of stem foliar versus basal methods, especially in the initial conversion following new line construction. The Volney–Marcy project was cleared and constructed between 1981 and 1982.



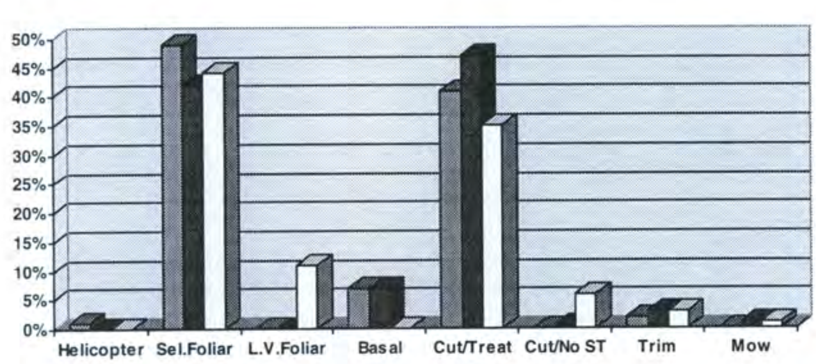

Graph 1. Cyclic comparison of undesirable density.

| | None | V. Light | Light | Medium | Heavy |
|---|---|---|---|---|---|
| 1st Cycle | 11% | 0% | 39% | 33% | 17% |
| 2nd Cycle | 17% | 0% | 43% | 33% | 7% |
| 3rd Cycle | 12% | 33% | 37% | 14% | 4% |

## APPLICATION METHODS

Beginning in 1978, field crews have been regularly trained to recognize desirable and undesirable vegetation, selectively targeting undesirables whenever practicable. While most of this is on-the-job training, periodically, systemwide meetings are conducted with all spray supervisors and their foremen to review field results, crew performance, and program goals and strategies. In the first years, undesirable densities were often so high the selective ground foliar applications were effectively broadcast foliar treatments. As undesirable densities have been reduced cycle-to-cycle, crews have become more selective. Graph 2 illustrates the treatment methods used through the years, and the relative percent of acres receiving each method.

Graph 2 identifies not only the preferred treatment methods, but how these treatments have changed over time. While helicopter was the method of choice in the 1960s and early 70s, it represented only 1% of the treatments during the first cycle. The last helicopter treat-




Graph 2: First, second and third cycle treatments methods (percentage of all acres treated). First cycle is bar on left, second cycle in middle, third cycle on right.

| | Helicopter | Sel.Foliar | L.V.Foliar | Basal | Cut/Treat | Cut/No ST | Trim | Mow |
|---|---|---|---|---|---|---|---|---|
| 1st Cycle | 1% | 49% | 0% | 7% | 41% | 0% | 2% | 0% |
| 2nd Cycle | 0% | 42% | 0% | 7% | 47% | 1% | 3% | 1% |
| 3rd Cycle | 0% | 44% | 11% | 0% | 35% | 6% | 3% | 1% |

ments were conducted in 1982. It remains an approved tool within the long-range management plan, for use in high density sites, and in remote, non-sensitive areas. From a practical stand point, these site conditions no longer exist.

Selective stem foliar applications are made during the summer, after full leaf development. The herbicide is transported through out the entire plant, following application, providing complete root kill. As a result, selective foliar treatments have become the method of choice in brushland and wooded sites. As undesirable densities in previous foliar sites have declined, cycle-to-cycle, we have been able to further refine the technique. The introduction of "low volume" foliar methods have also led to modification of conventional "high" volume equipment. This "modified" method uses 50 pounds per square inch (psi) nozzle pressure, rather than the conventional high volume 150 psi. It uses "hotter" mix rates, with 1.5% concentrate per hundred gallons of mix, rather than 1%. This combination of lower pressures require workers to get closer to the target stem, while hotter rates allows less herbicide mix per stem. The foliage does not have to be "wet to run off". As a result, the crews reduce over spray to non-target stems and the floor of the ROW. The adoption of this method has enabled our contractors to continue use of highly efficient hydraulic spray equipment, extending the useful life of existing equipment.

In 1992, low volume foliar (LVF) methods were introduced to the program, essentially replacing basal. LVF uses water borne mixes in the range of 4–5% concentrate, applied from back pack units. This is essentially the "marriage" of helicopter principles to basal equipment. While the foliar treatment is arguably the most effective herbicide treatment method, basal methods have been the least intrusive. The public generally expresses less concern with right-of-way crews during highly selective hand applications. The larger the equipment becomes, the more attention it is likely to draw. Finally, today's herbicides translocate well, providing complete root control using a wide range of products.

Basal applications have always been limited in nature on our system because of:

- the exacting coverage required to achieve control;
- the dislike by field crews carrying backpacks full of oil borne mixtures;
- the number of skips associated with highly selective, labor intense treatments;
- the higher amount of concentrate required per acre for the basal methods;
- and the higher chemical and labor rates of basal translate directly to higher costs per acre.

Cut and stump treatments have been the method of choice in public or environmentally sensitive sites, such as stream buffers, wetlands, near active crop fields and in and around sensitive residential, commercial or industrial areas. These treatments can be made at any time of year, except when snow depth restricts cutting stumps close to the ground and hampers efficient crew movement. While basal and stump treating are equally labor intense, and both provide the same percentage of skips, hand cutting insures that crews do not have to return to the site the next season to pick up their misses. After working through a particular site, they can easily survey the area to be sure no tall stems remain.

Graph 2 illustrates an increase in sites receiving no herbicide in recent years. More and more areas are receiving hand cutting only. This is a partially a result of ROW acquisition agreements on new lines where property owners expressly prohibit the use of herbicides as a condition of the easement. Unfortunately, we have one recent line where the company was ordered to construct in the easement of another state utility. Portions of that easement prohibit herbicide use. This accounts for most of these acres. However, non-herbicide requests and pressures will continue to be a challenge for ROW managers, with each becoming a site specific decision.

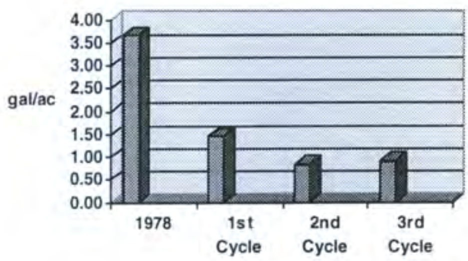
The trim sites have remained relatively constant. These are the yard trees where right-of-way agreements or owner concerns preclude their removal. In the last two years we have intensified pre-notification efforts on these sites, attempting to talk owners into removing fast or tall growing trees. We have had some success with this, but it requires an intense management effort. A knowledgeable forester must be assigned to the project, who can research right-of-way agreements, then meet and negotiate with the customer. Tree growth regulators may help our management efforts on these sites in the future.

Mowing has been found to be appropriate in some highly sensitive areas. However, without some form of herbicide follow up, coppice regrowth quickly shortens cycles to every two to three years. Mowing has been effectively used in certain residential areas where hand cutting costs become prohibitive, and high volume foliar treatment methods cause public concern. In the 1980s we used both cut stubble and basal follow up treatments after mowing. Today we try to follow up with a low volume foliar application, late in the first growing season after mowing.

## HERBICIDE USAGE

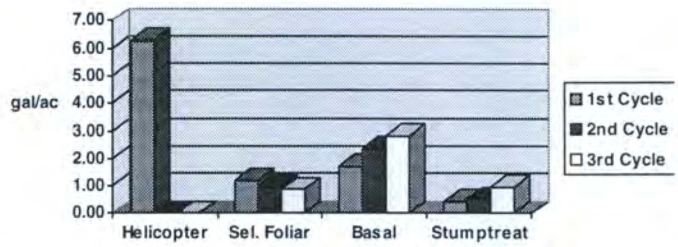
As mentioned earlier, when helicopter was used in the 1960s and early 70s, as much as 90% of that ROW could be aerially treated. If helicopter was not used, there was a heavy dependence on high volume ground foliar. The helicopter technique used highly concentrated mixtures of 25–30% herbicide, with rates exceeding 4–6 concentrate gallons/acre (gpa). By comparison, high volume ground foliar mixtures were 3–4% concentrate, and application rates were 3–9 gpa or more.

While 1978 represents the first year of the new IVM program, it also represents a transition year from these




Graph 3. Herbicide usage.

| | 1978 | 1st Cycle | 2nd Cycle | 3rd Cycle |
|---|---|---|---|---|
| Concentrate (gallons/acre) | 3.66 | 1.46 | 0.84 | 0.91 |




Graph 4. Cyclical comparison of herbicide usage by technique.

| | Helicopter | Sel.Foliar | Basal | Stumptreat |
|---|---|---|---|---|
| 1st Cycle | 6.26 | 1.18 | 1.71 | 0.44 |
| 2nd Cycle | 0 | 0.94 | 2.33 | 0.52 |
| 3rd Cycle | 0 | 0.86 | 2.79 | 0.96 |

non-selective broadcast methods of the past. The shift to selective, prescription treatment required intense training and field inspection as crews learned to recognize and save low growing species. Graph 3 plots herbicide use trends since 1978, showing that the average concentrate gallons/acre for the first cycle are 60% lower than the rates applied that first year. Results of the first cycle, clearly indicates the "buy in" of contractors and field crews to IVM methods. The third cycle rates represent a 75% reduction in the average concentrate gallons per acre since beginning the program.

Graph 4 illustrates the changes which have occurred in herbicide concentrate per acre, by technique, since 1978. A number of factors have contributed to the reductions which have occurred, including reductions in stem densities in foliar sites, improvements in herbicide effectiveness and application technology. However, analysis of the individual techniques indicate significant upward trends in herbicide usage on basal and stump treatment sites.

Following the public outcry of 1976, and the regulatory pressures to adopt highly selective methods within the long-range management plans, there was tremendous pressure to eliminate all foliar methods as well. In 1989, we were specifically directed to reduce dependence upon ground foliar methods, with individual regulators commenting that basal or cut and treat should be the only methods allowed. However, sound programming and application, together with extensive research through the Empire State Electric Energy Research Company (ESEERCo), the New York utilities have been successful in retaining selective ground foliar techniques as a viable tool.

Selective foliar methods provided a 20% reduction in gallons per acre of concentrate from the first to second cycle, and another 8.5% reduction from the second to third cycle. It has been the reductions in this category which contributed to the program's overall reductions in both stem density and herbicide usage.

Low volume foliar techniques, together with the modification of high volume methods are showing continued reductions are possible as crews and contractors witness the effectiveness and accept these methods. In 1995, our modified foliar rates required 0.77 gpa of concentrate, while low volume foliar rates were 0.69 gpa. We anticipate these rates will be further reduced through improved crew training and selectivity. The problem involves convincing applicators that effective control can be achieved with such light application rates to the leaf surface. The goal is to further reduce over spray, and consequent loss of non-target vegetation.

It is worth noting that the herbicide usage trends of foliar methods, as demonstrated by the overall density reductions, are consistent with finds of the previously mentioned Volney–Marcy research project.

The herbicide use trends for the basal technique indicate that it may be more environmentally intrusive than all other selective methods by introducing more herbicide per acre into the environment. Today, low volume foliar methods provide more effective control, while requiring far less herbicide.

Where foliar methods cannot be used due to public or environmental sensitivities, cutting and stump treatments are employed. Ironically, the high selectivity of this technique has not contributed to reductions in concentrate gallons per acre. Based on a doubling of herbicide rates per acre on stump treat sites, an increase in stem density is indicated. It is noteworthy that we have consistently used the same ready-to-use stump treatment products; Tordon RTU (Pathway) since 1980, and Compadre since 1991. We believe that this increase is the result of treatment skips or misses associated with stump treating, were crews overlook a cut stem, or wait too long after cutting before applying the herbicide. These misses are consistent with the basal method as well. Future conversion of these stumptreat sites to low volume foliar sites where possible, may improve results. However, we anticipate we will always have this problem since most stump treatment sites will continue to close to "sensitive" resources.

## COST TRENDS

For the right-of-way manager, costs and reliability are the factors which determine the effectiveness of your program. Graph 5 reveals the right-of-way maintenance trends which capture the attention and support of senior management.

The computerization of the program enabled us to:
- provide accurate vegetation density summaries and bid quantities to our contractors;
- modify the field inventory process, capturing decreases in undesirable density and again quantify them for our contractors:
- and identify reductions in herbicide usage,

This resulted in a change in our bid procedures in 1995. Prior to this time, all maintenance to the "floor" of the ROW, that is from tree line to tree line, was let to contract based on fixed price, lump sum bids. In 1995, we converted to unit price contracts, based on technique and density conditions. These changes have resulted in saving more than one million dollars per year and effectively maintaining today's acreage at less cost per acre than we paid in 1981.

## PUBLIC RELATIONS

The transition from high volume ground broadcast and aerial applications, to selective treatments, preserving compatible, low growing shrub communities have reduced customer concerns with vegetation management. The retention of this desirable vegetation has avoided the problem of extensive brown out. The establishment of buffers around "sensitive" sites has demonstrated concern for environmental or public concerns. Prescription programming essentially provides a "common sense" approach which is easy to explained and understood when responding to a customer concern or complaint. To assist in customer education, a "Long Range Right-of-way Management Brochure" has been developed. This brochure, together with the product label, is provided to any customer requesting additional information.

## CONCLUSION

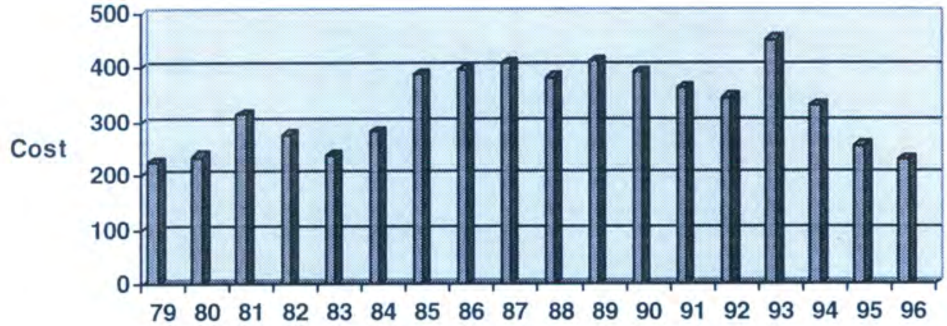
At Niagara Mohawk, we believe that the investment in a cyclical management program, spanning nearly two decades, and which employs integrated vegetation management principles and strategies, has been highly successful. The company is now enjoying significant cost savings. Our regulators can claim a major role in shaping right-of-way management policy in New York, increases in wildlife habitat and biodiversity, and reductions in herbicide usage while providing safe, reliable electric service. Our customers will enjoy reduced pressure for increased rates to support line clearance activities. Finally we are experiencing improved public acceptance of selective management strategies, especially the low volume technologies.

## REFERENCES


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

Egler, F.E. and S.R. Foote. 1975. Plight of the right-of-way domain: victim of vandalism. Futura Media Services, Mt. Kisco, New York.

Niagara Mohawk Power Corporation. Volney–Marcy vegetation management study: 1982–1990. December 1992. Final Report. NMPC, Syracuse, New York. 66 pp.


Graph 5. Average treatment cost per acre. Costs are not adjusted for inflation.

| | | | | | |
|---|---|---|---|---|---|
| 1979 | $226 | 1986 | $398 | 1993 | $452 |
| 1980 | $236 | 1987 | $409 | 1994 | $331 |
| 1981 | $316 | 1988 | $383 | 1995 | $256 |
| 1982 | $277 | 1989 | $413 | YTD 1996 | $231 |
| 1983 | $239 | 1990 | $392 | | |
| 1984 | $283 | 1991 | $364 | | |
| 1985 | $389 | 1992 | $346 | | |

## BIOGRAPHICAL SKETCHES

*Kenneth E. Finch*
*Niagara Mohawk Power Corporation, 300 Erie Blvd West, A-2, Syracuse, NY 13202, USA*

Kenneth E. Finch, Managing System Forester, holds a AS from Paul Smith's College, and a B.S. in Resource Management from SUNY College of Environmental Science and Forestry. Following the Army and a tour with Asplundh Tree Company, he joined NMPC as a Forestry Foreman and has risen through the ranks to become the Company's top forestry professional.

*Scott D. Shupe*
*Niagara Mohawk Power Corporation, 300 Erie Blvd West, A-2, Syracuse, NY 13202, USA*

Scott D. Shupe, Environmental Analyst at Niagara Mohawk, holds a B.S. in Biology and a M.S. in Water Resource Management from SUNY College of Environmental Science and Forestry, and a M.S. in Science Management from the University of Alaska-Anchorage. In consulting, government, and industry, his career has spanned the planning-construction-operations spectrum, including all elements of high-voltage power line construction contract management, small hydropower and navigation planning. He currently supports non-nuclear generation, gas, and electric system operating and licensing groups.

# Effectiveness of Three Vegetation Control Methods in Establishing Compatible Plant Species in Powerline Rights-of-Way in Northeastern Québec

**Yves Garant, Jean Domingue, and François Gauthier**

Hydro-Québec periodically controls vegetation in its powerline ROWs to maintain network security and reliability. The efficiency of three control methods in establishing compatible vegetation was tested in Northeastern Québec: (1) manual cut, (2) manual cut plus land application of Tordon 101 and TCA, and (3) aerial application of Tordon 101 and Silwet L-77. The purpose of the study was to compare the abundance of incompatible vegetation between sites, six years after the initial treatment. The area covered by incompatible stems was ranked based on three classes of vegetation homogeneity, using photogrammetry. Sampling plots were randomly distributed in vegetation zones in which the density of incompatible stems were measured and vegetation cover of mosses, herbs and grasses, woody vegetation and trees were determined. The most efficient method in controlling incompatible woody stems was aerial spraying of Tordon 101. Only 2,900 stems/ha were measured in these spans. Stem density of incompatible species was intermediate (14,184 stems/ha) after a ground application of Tordon 101 and TCA. A high density of 73,000 stems/ha was observed in spans that were treated by mechanical cutting.

*Keywords*: Herbicide, maintenance, manual cut, powerline, right-of-way, stems, TCA, Tordon 101, utility, vegetation

## INTRODUCTION

Hydro-Québec periodically controls vegetation in its powerline rights-of-way (ROWs) to maintain network security and reliability. Approximately 25% of these ROWs are located in remote areas or on rugged terrain where accessibility is often restricted. The efficiency of a treatment is based on its capacity to control incompatible vegetation (woody stems > 1 m high) that could eventually interfere with the network and cause a power failure. Vegetation control in northern ROWs located in the boreal forest is also a preventive measure for minimizing the risk of forest fires under powerlines. Methods that favor the establishment of low and stable vegetation communities are therefore favored by utilities (Brown 1993).

Hydro-Québec conducted a study in Northeastern Québec to test the efficiency of three vegetation control methods: (1) manual cut, (2) manual cut and terrestrial spraying of Tordon 101 and TCA (trichloroacetic acid), and (3) aerial spraying of Tordon 101 and Silwet L-77. A second cut was necessary in 1995 in spans treated by manual cutting in 1990 because vegetation was threatening the powerline. The objective of the study was to compare the effectiveness of each treatment, by measuring the abundance of incompatible vegetation at each site.

## STUDY AREA AND METHODS

The study was carried out in six spans of 2-735 kV lines located approximately 70 km north of Baie-Comeau, and in three spans of a 735 kV line, 35 km north of Godbout, on the North Shore of the Saint-Lawrence River (Fig. 1). Vegetation in these spans was controlled in 1990 by one of the following treatments (three spans/treatment):

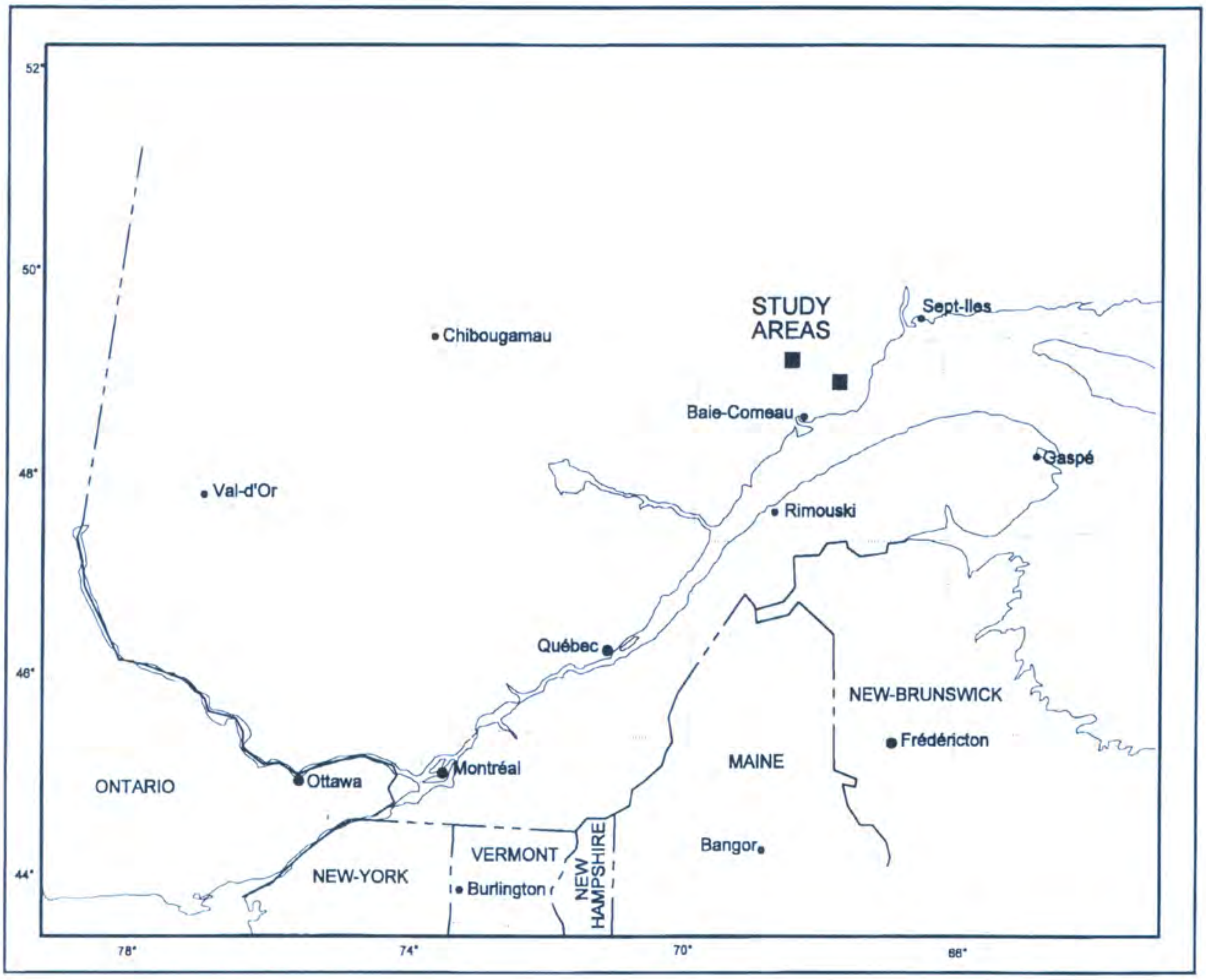



Fig. 1. Study areas in the North Shore region, Québec, Canada.

*Manual cut*: Systematic or selective cut of stems, 15 cm above ground, using chainsaws or other mechanical means. A second cut was necessary in 1995 because incompatible vegetation was threatening the powerline.

*Combined treatment*: All stems above 3 m in height were cut manually. A foliar spraying of Tordon 101 + TCA was applied thereafter by a vehicle equipped with a spraying gun. Herbicide was sprayed until run-off on leaves and stems occurred; volume of herbicide applied varied with density of incompatible vegetation. Concentrations of Tordon 101 and TCA in the mixture were 8.5 l/1000 l and 8 kg/1000 l, respectively.

*Aerial application of herbicide*: foliage was sprayed with a Tordon 101 with Sylwet-L-77 mixture using a TVB (Thru-valve boom) system mounted on a helicopter, at a rate of 25 l/ha of Tordon 101. This application was conducted at an approximate speed of 50 km/h and at an altitude of 4 m above vegetation. With a TVB, droplets measure ≈ 2000 μm in diameter and these droplets are therefore less prone to drifting than fine droplets formed by conventional sprayers.

A preliminary examination of the vegetation in each span was conducted by photogrammetry. Homogeneous vegetation zones were delineated using three classes of incompatible stem density. Zone 1 was dominated by compatible vegetation (herbs, grasses, forbs, low shrubs) and incompatible stems were sparse. Zone 2 was characterized by small clumps of incompatible species; these clumps accounted for less than 50% of total vegetation cover. Zone 3 was defined as an area in which vegetation cover of incompatible stems was equal or greater than 50%. The area covered by each vegetation zone was measured in all spans.

Sampling plots (3.57 m radius) were randomly distributed in each vegetation zone. Poles were tallied by diameter at breast height (DBH) and height for stems with a DBH ≥ 1 cm, as defined in Québec (1984) (Table 1). Stems with a DBH < 1 cm were recorded by species in 1.13 m radius sampling plots (Fig. 2). In aerially sprayed spans, vegetation zones 2 and 3 were virtually absent and all sampling plots were distributed in zone 1 (Table 2). Density of incompatible vegetation is presented separately for coniferous and deciduous species for two stem classes: regeneration (DBH < 1 cm) and poles (DBH ≥ 1 cm).

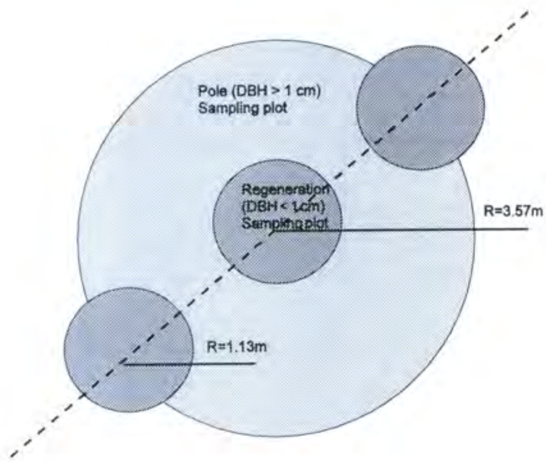



Fig. 2. Spatial location of sample plots used to measure density and cover of incompatible vegetation in rights-of-way.

**Table 1. Diameter at breast height (DBH) and height classes used to classify vegetation**

| Class | DBH (cm) or Height (m) |
|---|---|
| DBH | |
| 2 | 1–1.9 |
| 4 | 2–3.9 |
| 6 | 4–5.9 |
| 8 | 6–7.9 |
| Height | |
| 3 | 1–1.9 |
| 4 | 2–2.9 |
| 5 | ≥ 3 |

## RESULTS AND DISCUSSION

### Density of incompatible vegetation

Abundance of incompatible vegetation varied greatly with treatment; a very low density of 2,901 stems/ha was measured in aerial sprayed spans whereas 73,100 stems/ha was recorded in cut spans (Fig. 3). Regeneration was the dominant stem class in all treatments and it accounted for 71–98% of incompatible vegetation in the ROWs. No deciduous poles were recorded six years after treatment in spans treated with an aerial application of Tordon 101. Deciduous and coniferous poles were the most abundant after a combined treatment (cut and herbicide) (Fig. 3).

Manual cutting of vegetation was the least efficient method in controlling incompatible stems. One year after a second cut, stem density was 25 times more abundant than density six years after an aerial application of Tordon 101.

### Vegetation cover

Moss cover in spans treated with herbicides (36–47%) was greater than cover in spans treated by a mechanical cut (7–12%). Low herbs and grasses dominated most study areas with a vegetation cover between 40 and 74% (Table 3). This type of vegetation was very common in Tordon 101 treated areas and it occupied about 67% of the span. Tall herbs and grasses were also abundant and this class covered 20–55% of vegetation zones (Table 3).

Low woody vegetation was present at all treated sites and represented from 16 to 46% of the areas. Tall woody stems were not common in Tordon 101 aerially treated spans, with a cover of only 7% (Table 3). Tall incompatible stems (1 m ≤ height ≤ 2.9 m) were common or abundant in zones 2 and 3 of the manual cut and combined treatments with a cover between 39 and 63%. Stems above 2.9 m were recorded only in spans where vegetation was controlled by the combined or cut

**Table 2. Distribution of sampling plots in vegetation zones**

| Treatment | Vegetation zone* | Large sampling plots 3.57 m radius (n) | Small sampling plots 1.13 m radius (n) |
|---|---|---|---|
| Aerial spraying (Tordon 101) | 1 | 10 | 30 |
| Combined treatment (cutting stems > 3 m, | 1 | 5 | 15 |
| terrestrial spraying of Tordon 101 and TCA) | 2 | 6 | 18 |
| | 3 | 5 | 15 |
| Cut | 1 | 6 | 18 |
| | 2 | 8 | 24 |
| | 3 | 5 | 15 |
| | Total | 45 | 135 |

* Zone 1: Dominated by compatible vegetation.
Zone 2: Small clumps of incompatible cover, < 50% vegetation cover.
Zone 3: > 50% of incompatible vegetation cover.

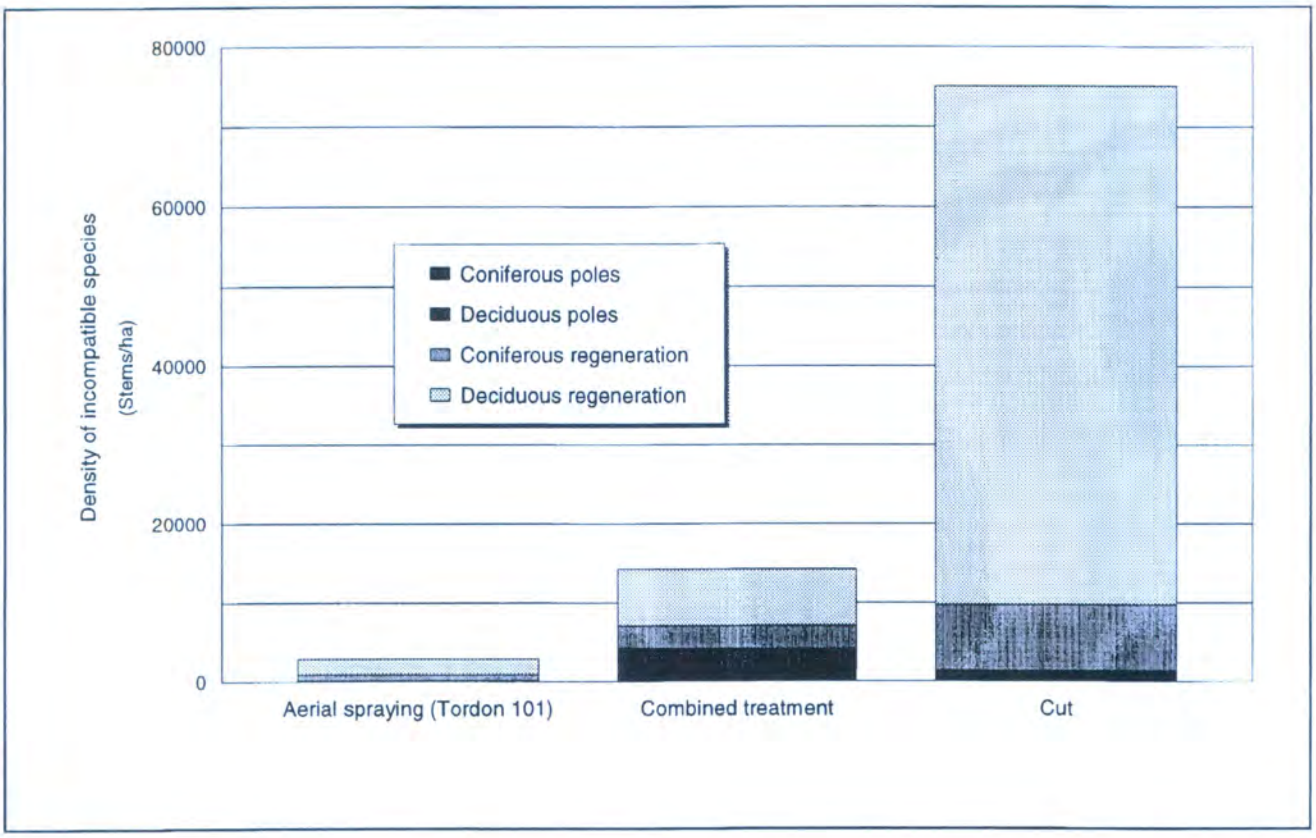



Fig. 3. Stem density of incompatible species for 3 types of vegetation control.

**Table 3. Percent cover of vegetation classes in treated spans of powerline rights-of-way**

| Treatment | Zone* | Area | Cover (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mosses | Low herbs and grasses | Tall herbs and grasses | Low woody stems | Tall woody stems | Trees | Barren |
| Aerial spraying (Tordon 101) | 1 | 12.80 | 36 | 67 | 55 | 24 | 7 | 0 | 0 |
| | 2 | 0.39 | – | – | – | – | – | – | – |
| | 3 | 0.01 | – | – | – | – | – | – | – |
| Combined treatment (cutting stems > 3 m, terrestrial spraying of Tordon 101 and TCA) | 1 | 6.30 | 37 | 40 | 36 | 24 | 6 | 0 | 4 |
| | 2 | 7.79 | 47 | 70 | 20 | 16 | 42 | 3 | 0 |
| | 3 | 3.06 | 45 | 74 | 42 | 24 | 63 | 26 | 0 |
| Cut | 1 | 2.40 | 12 | 49 | 35 | 46 | 9 | 0 | 0 |
| | 2 | 2.22 | 7 | 46 | 31 | 40 | 45 | 1 | 0 |
| | 3 | 2.50 | 7 | 41 | 33 | 17 | 39 | 10 | 0 |

*Zone 1: Dominated by compatible vegetation.
Zone 2: Small clumps of incompatible cover, < 50% vegetation cover.
Zone 3: > 50% of incompatible vegetation cover.

treatment (Table 3). Most of these stems were found in zone 3, where density of incompatible vegetation was the highest.

Based on the growth pattern and the characteristics of the vegetation (height and density) in 1996, six years after the aerial spraying and combined treatments, and one year after a second cut, we anticipate a treatment cycle of nine years for the aerial spraying of Tordon 101, seven years for a combined treatment and about four to five years for a manual cut.

## REFERENCES

Brown, D. 1993. The formation of stable rights-of-way vegetation with cover crops — How do you choose which species to plant? Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montréal, Québec. pp. 70–75.

Québec. 1984. Normes d'inventaire forestier. Ministère de l'Énergie et des Ressources du Québec. Gouvernement du Québec. 177 pp.

## *BIOGRAPHICAL SKETCHES*

***Yves Garant***

*Naturam Environnement, 31 Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*

Yves Garant holds a M.Sc. degree in Renewable Resources from McGill University and has been working as a wildlife consultant since 1986. He has conducted several research projects in rights-of-way management for Hydro-Québec. His main research interests are ungulate and furbearer ecology and management.

***Jean Domingue***

*Naturam Environnement, 31 Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*

Jean Domingue is president and director of Naturam Environnement Inc. since 1985, a consulting firm specialized in Biology, Forestry, and Environment. His areas of interest are diverse and include application of high-technology in resource management, vegetation maintenance in utility rights-of-way, industrial monitoring and impact assessments.

***François Gauthier***

*Hydro-Québec, Direction principale Communication et Environnement, 75 Boulevard René-Lévesque Ouest, 16$^{e}$ étage, Montréal, Québec, Canada, H2Z 1A4*

François Gauthier obtained a B.Sc. degree in Forestry in 1980 and a M.Sc. degree in Environment in 1992. He has been working for Hydro-Québec for 15 years in the vegetation control field, more specifically on the environmental aspect of this activity. He has conducted many research projects and studies in this area and has developed an integrated approach to vegetation maintenance.

# The Houston Region Native Grass Seedbank: A Natural Partnership Between Right-of-Way Management and Conservation

**Robert A. Honig and Gregory D. Wieland**

Native grasses, especially local ecotypes, are better adapted to local conditions than many non-native species used on rights-of-way. Once established they require less maintenance and are more drought hardy than these non-native species, and their deeper root systems better prevent soil erosion. They also provide quality habitat for native fauna, helping maintain biodiversity. However, native grass communities are disappearing due to agriculture, noxious weed and brush encroachment, and urbanization. Furthermore, seeds of southeast Texas ecotypes are not commercially available for revegetation efforts, as on rights-of-way. Thus, in August 1995, representatives of government agencies, businesses, and conservation organizations established a Houston Region Native Grass Seedbank to ensure a substantial future source of grasses indigenous to the southeast Texas coastal prairie. To develop a protocol for restoring a site dominated by undesirable species to one dominated by native species, El Paso Energy provided approximately 0.8 ha (2 acres) for experimental plantings within a natural gas pipeline compressor station. Criteria for choosing species used in 1996 were desirability of preserving the local ecotype, ease of growth, ease of identification, erosion control potential, wildlife values, aesthetics, and availability during collection dates. Despite severe early summer drought, all planted species germinated and set seed; Longspike Tridens and Big Bluestem demonstrated enhanced potential for rights-of-way by outcompeting the aggressive, non-native grasses. Efforts are continuing in 1997. The Harris County Flood Control District, Houston Lighting & Power Company, and Mercer Arboretum and Botanic Gardens are also involved in cooperative efforts with the Seedbank Project.

*Keywords*: Prairies, grasses, restoration, rights-of-way, pipelines, native plants, conservation, erosion control, seed bank, business/conservation partnerships, Texas

*Prairie. Here was the continent's largest continuous ecosystem, and the one most characteristic of the United States. Today it is the rarest and most fragmented, the one in gravest danger of vanishing altogether*
— Chadwick (1995)

The Houston Region Native Grass Seedbank Project (hereafter referred to as "Seedbank Project" or "Seedbank") is a consortium of institutions and individuals striving to make available substantial quantities of locally adapted native grass seed, as well as to publicize the utility and value of native grasses and the prairies where they grow. By illustrating the desirability and beauty of grasses native to southeast Texas, and by creating an appreciation of these grasses, the Seedbank Project hopes to contribute to the conservation of their habitat, the disappearing coastal prairie.

Because these grass species have qualities that make them well suited for use on rights-of-way[1], pipeline and electric transmission companies and transportation corridor (i.e., highways and railroads) managers can play an important role in the conservation and restoration of the coastal prairie. This seed bank concept being developed in the Houston, Texas, region has widespread applicability: over 99% of the original prairies

1 "Right-of-way" in the context of this article means a linear corridor; it does not include compressor/pumping stations, meter stations, processing facilities, electric substations, power plants, or other ancillary facilities.

throughout North America have disappeared, and they continue to disappear at alarming rates as they are converted to other uses (Bohnen and Hanchek 1992).

## THE NEED FOR A COASTAL PRAIRIE SEED BANK IN SOUTHEAST TEXAS

Prairies are characterized by grasses with extensive root systems, usually with many other herbaceous plants, sometimes called forbs, and with trees and shrubs playing a minor role. Mycorrhizal fungi associated with the grasses' root systems symbiotically enhance the grasses' uptake of nutrients and water. Prairie fauna — from soil microinvertebrates to ants to bison — are associated as well. The domination of grasses is facilitated by periodic drought, grazing, and wildfire (Chadwick 1995). Coastal prairies in Texas and Louisiana extend 50 to 130 km (30 to 80 miles) inland from the marshes along the Gulf of Mexico. They are nearly level, with elevations from sea level to 75 m (250 ft) (Hatch et al. 1990).

The coastal prairies of Texas and Louisiana once covered about 5.3 million ha (13 million acres). Today, however, less than 2% remains, mostly under private ownership. The remaining 100,000 ha (250,000 acres) are facing human and agricultural pressures with about one-third of the area cultivated for rice, sorghum, corn, and tame pastures (Wagner and Riskind 1992). Much of the rest is threatened by aggressive non-native (also called exotic or noxious) invaders — most introduced intentionally by man — which have little value to native wildlife and can outcompete native plant species. For example, the 80 km (50 mile) drive from Houston to Galveston — which once presented sweeping vistas of native grasses — is now to a large extent dominated by views of Chinese Tallow (*Sapium sebiferum*) thickets. In 20 years from the time it first invades a prairie, this tree species is capable of developing into an essentially monoculture climax overstory that is biologically depauperate (Cameron 1996). In fact the status of the remnants of coastal prairie is evidenced by the Louisiana Natural Heritage Program's classification of coastal prairie as "critically imperiled" (Smith 1996) and the Texas Natural Heritage Program's (1993) classification of the Little Bluestem–Brownseed Paspalum community as "imperiled" and the Gammagrass–Switchgrass community as "critically imperiled."

Some of the individual grass species and other rare plants with which they are associated are in danger of becoming extinct. For example, Texas Windmillgrass (*Chloris texensis*)[2] is known from only about ten sites in the shrinking prairies of the Houston region (Arey 1996). Sites for this rare grass are disappearing rapidly. Possibly the best location was transformed in 1994 to a suburban yard, complete with ranch house and two trees in the front yard. Another site in Pasadena, Texas, was developed, with the accompanying loss of Texas Windmillgrass as well as another rare species, the Houston Daisy (*Machaeranthera aurea*). Two other sites will be lost due to construction of a highway and a mall.

Who cares? Who needs these fields of grasses and forbs? What good are they? They provide habitat for a wide variety of dependent wildlife, including many migratory birds and endangered species like Attwater's Prairie Chicken (*Tympanachus cupido attwateri*). Prairies may be an important sink of carbon dioxide, of growing importance in light of concern over global climate changes. And centuries of growth and decay of the extensive root systems and vegetative matter, along with periodic wildfires, have produced the richest soils in the world. Prairies not only improve soil, but they can be hayed, and they provide forage for livestock. In fact, because no fertilizer is required and water is not as critical, the expense of managing native forage is much less than for managing so-called "improved" grass species (Campbell 1996). This invaluable natural resource has enhanced quality of life in the United States and enabled it to become the "breadbasket of the world". Prairies thus have a historic importance equal to that of any man-made site. However, instead of protecting this valuable resource, mankind has considered prairies expendable — plowing them, depleting the soil and allowing it to erode, and covering the world's best soils with subdivisions, malls, and roads. As a result, prairies have become perhaps the most threatened habitat in the United States.

## THE HOUSTON REGION NATIVE GRASS SEEDBANK PROJECT

Fortunately, there is growing interest in prairies and in using native grasses for prairie restoration, landscaping, erosion control, soil stabilization, and flood control projects. The only economical way to establish prairie plants on a large scale is with seed. Unfortunately, in the case of the Gulf coast of Texas there are no sources of locally adapted native grass seeds. Most commercially available native grass is derived from material collected in other areas of the country, such as Kansas and west and north Texas, and has been bred to reduce genetic variability (producing strains called "cultivars"). This material is adapted to climates and soils different from those on the Gulf coast, and thus it is unlikely to perform as well as local ecotypes if transplanted to southeast Texas. A Minnesota study (Olson 1984) illustrated this, finding that grass varieties derived from Nebraska stock flowered up to 60 days later than the local ecotype, resulting in frequent winter injury.

The need for a source of locally adapted grass seed prompted the establishment in August 1995 of the Houston Region Native Grass Seedbank Project. The

2 Nomenclature of grass species as in Gould (1975).

following organizations are represented on the Seedbank Project team:

- U.S. Fish & Wildlife Service
- Sims Bayou Coalition
- Katy Prairie Conservancy
- El Paso Energy[3]
- University of Houston Coastal Center
- Texas Parks and Wildlife Department
- Houston Lighting and Power Company
- Harris County Flood Control District
- Mercer Arboretum and Botanic Gardens
- Brown & Root
- Native Plant Society of Texas

The goals of this project are to develop cost-effective methods of producing ready and substantial supplies of seed of locally adapted native grasses, determine how to best establish new stands, demonstrate the grasses' utility and desirability, and encourage the use of these grasses. Hopefully in a few years commercial interests, stimulated by consumer demand, will discover the market, use and improve the methods, and take over the project, making locally adapted material widely available for the first time as they profit from this currently untapped commodity.

Initial efforts of the project included seed collecting by volunteers in the autumns of 1995 and 1996 from several remnant prairie sites in the Houston region, and organizing and co-sponsoring the highly successful Coastal Prairie and Native Grasses Symposium in October 1996 at the University of Houston-Clear Lake.

## THE EL PASO ENERGY-SEEDBANK PROJECT PARTNERSHIP: A RIGHT-OF-WAY COMPANY CASE STUDY

### What's in it for a right-of-way manager such as El Paso Energy?

The El Paso Energy system contains more than 56,000 km (35,000 miles) of natural gas pipeline in 24 states. Sections of right-of-way for small diameter pipelines may be as little as 4.6 m (15 ft) wide, others for large diameter lines may occupy corridors 15.2–22.9 m (50–75 ft) wide, and for multiple lines the corridors may be wider than 30.5 m (100 ft). El Paso Energy maintains the right-of-way in a low-growth condition (e.g., grasses) to facilitate surveillance and provide access for maintenance and emergency response, as well as to minimize the chances of woody plant roots damaging pipe coatings. Thus the vegetation on the right-of-way significantly influences the maintenance effort El Paso Energy must expend.

Erosion control, one of the major criteria for choosing species for the Seedbank, is also of particular concern to right-of-way managers. Severe erosion can cause safety problems, and it will generate complaints from landowners and raise concerns among government agencies that have issued operating permits. Using native grasses with deep root systems — some as deep as 4–6 m (12–20 ft) — can enhance the soil-holding ability of the right-of-way vegetation.

In addition, because native species are better adapted to local conditions, once established they require less care and are more drought hardy than many commonly used non-native species. Thus, enhanced drought hardiness and erosion control can increase right-of-way maintenance efficiencies and in turn reduce dollars spent.

The environmental conservation aspects of the project can generate positive publicity for a corporate partner and enhance relationships with the community, conservation organizations, agencies, and others. Locally adapted native grasses represent the unique qualities of the local plant community. Because prairies provide habitat for a wide range of native plants and animals, they help maintain a region's biodiversity. Thus, support can be expected from a wide range of interests such as native plant societies, nature clubs, students, and government agencies with an interest in managing similar habitats.

In addition, depending on the success of the Seedbank's efforts and how widely this approach can be implemented, there is potential to use company property to grow these species commercially. El Paso Energy would then be able to use its own seed on its rights-of-way. The company also could sell seed to supplement the corporate bottom line — always an attractive prospect to management. The acreage on which such an operation is located might even qualify for an agricultural tax exemption.

Of course, there are some concerns that must be addressed when revegetating with native grasses. For example, it may be imperative to quickly establish vegetation, e.g., to minimize erosion. In this case, one can use nurse plants, low-competitive exotic species that will establish themselves quickly but later be edged out by the slower-establishing native grasses. Also, some non-natives such as Bahiagrass are extremely aggressive and tough to kill, thus they can be expensive and labor intensive to eliminate.

### The experimental planting site

El Paso Energy's contribution to the Seedbank Project was to make available an approximately 0.8 ha (2 acre) pilot project site for the sowing of grass seed. The goal of this experiment: to develop a protocol for restoring a site dominated by undesirable species to one dominated by native species.

The pilot site is at El Paso Energy's Compressor Station 17 near East Bernard, Texas, in Wharton County. It is in a portion of the facility formerly used

3 Pipeline company involvement in the Seedbank Project began at Tenneco Energy, prior to its merger with El Paso Energy Corporation in December 1996. Work on the project continues under El Paso Energy's management. All references in this article, even to events prior to the December 1996 merger, will be to El Paso Energy.

**Table 1. Native Grass plantings at the El Paso Energy compressor station, Wharton County, Texas**

| | Amount | Area planted | Application rate[1] |
|---|---|---|---|
| Species: seed sowing | | | |
| Florida Paspalum (*Paspalum floridanum*) | 0.36 kg (0.79 lb) | 266 $m^2$ (2,868 $ft^2$) | 13.5 kg/ha (12.0 lb/ac) |
| Switchgrass (*Panicum virgatum*) | 0.17 kg (0.37 lb) | 214 $m^2$ (2,302 $ft^2$) | 7.9 kg/ha (7.0 lb/ac) |
| Longspike Tridens (*Tridens strictus*) | 0.36 kg (0.8 lb) | 360 $m^2$ (3,872 $ft^2$) | 10 kg/ha (9.0 lb/ac) |
| Big Bluestem (*Andropogon gerardii*) | 1.08 kg (2.37 lb) | 799 $m^2$ (8,603 $ft^2$) | 13.5 kg/ha (12.0 lb/ac) |
| Pan American Balsamscale (*Elyonurus tripsachoides*) | 1.74 kg (3.84 lb) | 1,295 $m^2$ (13,939 $ft^2$) | 13.4 kg/ha (12.0 lb/ac) |
| Species: seed hay application | | | |
| Little Bluestem (*Schizachyrium scoparium*) | 1,150 kg (2,535 lb = 39 bales) | 5,159 $m^2$ (55,536 $ft^2$) | 2,229 kg/ha (2,000 lb/ac) |

[1] Pure live seed % not determined.

for company housing and thus removed from day-to-day compressor station operations. There is no high-pressure underground gas piping in this part of the facility; however prairie grass planting and maintenance do not involve any deep plowing or digging and would not present any safety concerns even if they were conducted over buried pipes (e.g., on a right-of-way).

### The experimental plantings

Site preparation involved application of the herbicide Roundup™ to eliminate Bahiagrass (*Paspalum notatum*), King Ranch Bluestem (*Bothriochloa ischaemum* var. *songarica*), and other aggressive, non-native grasses that dominated the site so that the native prairie grasses would have less competition. In addition compressor station staff disked the soil twice to kill the Bahiagrass roots. The Seedbank team originally targeted planting for January 1996 in order to have the seed in the ground early enough to take advantage of the spring rains. However, winter frosts, lingering cold weather, and extended drought had killed the tops of the Bahiagrass. Because Roundup™ works best on actively growing plants, the team was forced to delay herbicide application until March when the Bahiagrass started growing again.

On 21 March 1996, the team sowed monoculture strips totaling approximately 0.3 ha (0.7 acres) with seeds of five native prairie grasses collected by Seedbank volunteers in southeast Texas: Pan American Balsamscale (*Elyonurus tripsachoides*) from the Attwater Prairie Chicken National Wildlife Refuge in Colorado County; and Switchgrass (*Panicum virgatum*), Longspike Tridens (*Tridens strictus*), Big Bluestem (*Andropogon gerardii*), and Florida Paspalum (*Paspalum floridanum*) from the University of Houston Coastal Center in Galveston County. The Seedbank team chose these species based on desirability of preserving the local ecotype, ease of growth, ease of identification, potential for preventing erosion, wildlife values, aesthetics, and availability during collection dates. Sowing was by hand — unfortunately, the seed drill available to the Seedbank team would not work in the soil at the site, despite grading beforehand. Table 1 contains the amounts, areas seeded, and application rates. Compressor station staff rolled this portion of the site immediately after sowing to minimize seeds' blowing away and to ensure seed-soil contact. (Rolling involves pulling a water-filled cylinder behind a tractor; the weight of the cylinder pushes the seed into the soil.) About one week later, the team mulched the hand-sown seed with three-year-old native hay from the Attwater Prairie Chicken National Wildlife Refuge, about 15 miles from the compressor station. A straw blower provided by the U.S. Fish and Wildlife Service chopped the hay and shot it evenly onto the planting site.

In addition, on 21 March 1996 on 0.5 ha (1.3 acres) of the site the team used the straw blower to spread Little Bluestem (*Schizachyrium scoparium*) seed hay harvested from the International Paper Farms of Texas in Brazoria County. Use of seed hay appears to be a promising strategy, as the hay not only contains seeds but also provides its own mulch, thus better retaining soil moisture. The team also rolled this portion of the site immediately after spreading the hay.

Because of the drought, Compressor Station staff initially irrigated the site, but subsequently the Seedbank team just let nature take its course. Despite the irrigation, drought appeared to compromise initial germination of the experimental plantings.

*17 July 1996 site visit:*

Bahiagrass had germinated and once again dominated the bulk of the site, despite the pre-planting herbicide treatment. Some of the sown native grass seed likely had germinated; however, with the exception of one swath of Longspike Tridens, the Seedbank team could not confirm this because it is extremely difficult to identify many of the grasses before they mature. The Seedbank team mowed the entire site with the blade set high (15 cm [6 in]) to knock back the Bahiagrass and then let nature take its course.

*12 September 1996 site visit:*

Room for optimism. Small amounts of Florida

Paspalum, Longspike Tridens, Big Bluestem, and Pan American Balsamscale had matured and gone to seed. In addition some Brownseed Paspalum (*Paspalum plicatulum*) appeared: this is a desirable native species that was not among the species knowingly planted by the Seedbank Project, however propagules may have been in the seed hay. The Switchgrass apparently had not germinated, nor had the Little Bluestem seed hay.

*20 November 1996 site visit:*

The most positive results yet. Little Bluestem seed hay had finally germinated and in good numbers. Switchgrass made its first appearance, thus all five planted species were present and had gone to seed. Longspike Tridens was still in high abundance in its row, and there were several patches of Big Bluestem that had not set seed. Because these two species, especially the Tridens, outcompeteted the non-native species, they may have enhanced potential for use on rights-of-way. There were still large numbers of undesirable grasses such as Bahiagrass, crabgrass, and a large patch of King Ranch Bluestem in the northeast corner of plot (the compressor station turf, where this species is present, is likely the source). Most of the seed of the desired species had already dispersed, providing a source for further germination. In addition, the team also collected some of the small amount of seed that had not yet dropped, as well as seed of a mix of species from a site within a mile of the Compressor Station. The Seedbank Project can use these at the experimental plot at the compressor station should supplemental plantings be needed, or at other revegetation sites in southeast Texas.

### Activities planned for 1997 at the El Paso Energy Site

El Paso Energy management approved plans for a prescribed burn in early 1997 of the experimental plots in the compressor station. Such burns simulate conditions in which the native species grow best (i.e., natural wildfires): their deeper roots will allow survival preferentially over the non-native species, which generally have shallower roots and are thus less fire resistant. Furthermore, Texas Natural Resource Conservation Commission (1996) regulations authorize "prescribed burning [without an air emissions permit] for ... range and wildland / wildlife management purposes." Unfortunately, wet weather and unfavorable winds prevented the Seedbank team from conducting the burn. Plans now are to mow the site, determine the need for spot-application of herbicide (Roundup™) to eliminate undesirable species, monitor and assess results, and hope that conditions in early 1998 are favorable for a prescribed burn. From a community relations perspective, plans are to erect a sign to generate public awareness of El Paso Energy's cooperative effort with the Seedbank Project.

### Will landowners be receptive to planting native grasses on pipeline rights-of-way?

Initially, El Paso Energy considered finding a site on one of its pipeline corridors. However, El Paso Energy, like most pipeline companies, does not own most of its rights-of-way — in fact it is held as easement. Standard right-of-way agreements with landowners prohibit erecting structures and deep plowing and digging over the pipeline; also, the pipeline company will cut any tall trees over the pipe (so the roots don't damage the pipe coatings). Beyond this, a pipeline company generally cannot control what the landowner does. Much of the right-of-way in Texas is in agriculture, and landowners growing a cash crop likely would be hesitant to let a swath of native grasses cross their property and disrupt their operations. Thus, pipeline companies must develop economically viable strategies in order to obtain permission to plant native grasses from owners of inactive cropland, pasture, hay fields, or non-agricultural land. The authors are optimistic that the lower cost of managing native grasses versus non-native species (Campbell 1996) will be a persuasive argument.

## OTHER SEEDBANK ACTIVITIES

### Harris County Flood Control District project at Sims Bayou (Koros 1996)

In early 1994 the Sims Bayou Coalition requested the U.S. Army Corps of Engineers (COE) to investigate the use of native grasses to revegetate the banks of Sims Bayou in an urban area on the south side of Houston. COE had proposed using entirely Bermudagrass (*Cynodon dactylon*). The need for native grass seed for this project played a major role in bringing about the formation of the Seedbank Project.

COE initially expressed concern that the grasses might impede water flow. However, a demonstration in 1995 using plantings of mature native grass species confirmed to the satisfaction of the COE that these species caused no significant hydrology problems. The American Society of Landscape Architects and the Sims Bayou Coalition had purchased the mature plants and donated them to the Harris County Flood Control District in order to eliminate waiting for the grass to grow from seed, thereby obtaining quick results. The species used in this demonstration project were: Mason Sandhill Lovegrass (*Eragrostis* 'Mason Sandhill'), *Canada Wildrye* (*Elymus canadensis* var. *canadensis*), Eastern Gamagrass (*Tripsacum dactyloides*), Gulf Muhly (*Muhlenbergia capillaris*), Alamo Switchgrass (*Panicum virgatum* 'Alamo'), Knotroot Bristlegrass (*Setaria geniculata*), Prairie cordgrass (*Spartina pectinata*), Little Bluestem, and Indiangrass (*Sorghastrum nutans*).

These first plantings along Sims Bayou also demonstrated the need for more intensive control of non-native species which aggressively competed with the native grasses. As a result, the subsequent stages of this project evaluated site preparation techniques, specifically solarization, which entails covering the site with clear plastic so that solar radiation generates elevated soil temperatures. The initial solarization in winter 1995-96 was somewhat effective: raised temperatures stimulated early germination of seeds in the soil; this was followed by application of glyphosate herbicide in hopes of depleting the seed bank of noxious species in the soil, however the residual seed bank still produced an overly competitive non-native crop. In contrast, summer solarization, with sustained soil temperatures of up to 65°C (150°F), was extremely effective without herbicide, killing even Johnsongrass (*Sorghum halepense*) rhizomes, Annual Sunflower (*Helianthus annuus*), non-native Morning Glory (*Ipomoea* sp.), and Snout Bean (*Rhynchosia* sp.). In addition, a portion of the seeds used at Sims Bayou were greenhouse-germinated and planted as plugs; the success of these plantings demonstrates that using plugs can be very effective, although probably not cost-effective on a large scale. As of early 1997, monoculture strips of Big Bluestem, Silver Bluestem (*Bothriochloa saccharoides*), Pan American Balsamscale, Gulf Muhly, Switchgrass, Florida Paspalum, and Longspike Tridens are thriving on the banks of Sims Bayou.

### Houston Lighting & Power Company efforts (Baker 1996)

Houston Lighting & Power Company (HL&P) became involved in the Seedbank Project in autumn 1995. HL&P's initial effort in February 1996 involved application of 1000 bales of prairie seed hay to a disked 8 ha (20 acre) site at its South Texas Nuclear Project in Matagorda County. This hay came from International Paper Farms of Texas in Brazoria County, the same source as the seed hay used at the El Paso Energy site. Also cooperating were the U.S. Fish and Wildlife Service — which provided the straw blower to mulch and spread the hay prior to application — and the Sam Houston Resource Conservation District. The five major species anticipated — Little Bluestem, Big Bluestem, Indiangrass, Eastern Gammagrass, and Longspike Tridens — have germinated along with other native species. HL&P anticipates it will be approximately five years before the site matures.

In addition to that site, HL&P set aside 40 ha (100 acres) of transmission line right-of-way in Galveston County, Texas, for harvest of both Big Bluestem and Little Bluestem seed, and to provide propagation sites for select species of interest. HL&P is in the process of identifying additional acreage for similar projects.

### Seed viability testing at Mercer Arboretum and Botanic Gardens

If seeds are going to be stored and subsequently used for various projects, certain question must be answered. Are the collected seeds viable and what percent will germinate? Can the seeds tolerate standard long-term storage techniques in which they are dried and frozen (e.g., rice, which is a grass, cannot tolerate this treatment)? Do the seeds have an innate dormancy? If so how can this dormancy be broken? Knowing the germination requirements is important information that will assist anyone who intends to plant seeds and manage planting sites. Mercer Arboretum and Botanic Gardens, with its established seed storage and testing facilities, has initiated tests on some of the seed lots collected for the Seedbank in order to answer these questions. Mercer Arboretum and Botanic Gardens also is displaying specimens to increase public awareness of the beauty and utility of these grasses.

## CONCLUSIONS

1. Native grasses have high potential for use on rights-of-way because of their deep root systems that promote erosion control and their adaptation to local conditions — especially drought — that will reduce maintenance efforts.
2. The efforts of Houston Region Native Grass Seedbank promote the use and appreciation of native prairie grasses and will lead to the conservation of this important component of Texas's heritage. Thus prairies will be available for the enjoyment and utilization of future generations.
3. Pipeline, electric, railroad, and highway rights-of-way can play an important role as seedbanks for native plant species. Right-of-way managers have opportunities to partner with the public sector and even help initiate seed bank efforts in numerous habitats. El Paso Energy's work with the Houston Region Native Grass Seedbank Project is an example of such a partnership.
4. Experimental plantings at the El Paso Energy compressor station in Wharton County, Texas, show promise that a southeast Texas site dominated by non-native grasses can be restored to one dominated by native species.
5. Longspike Tridens and Big Bluestem outcompeteted the non-native species, indicating enhanced potential for use in competitive situations.
6. Right-of-way managers must work cooperatively with landowners to develop economically viable strategies in order to obtain permission to plant native grasses from owners of inactive cropland, pasture, hay fields, or non-agricultural land.

## ACKNOWLEDGEMENTS

The continuing support of El Paso Energy management and staff, especially in providing on-site logistical support for the efforts at Compressor Station 17, has been vital to the progress of the Seedbank efforts. In particular, Bubba Brandes served as the compressor station's liaison with the Seedbank Project team, providing insight on local planting conditions and spending considerable time and energy in herbicide application, disking, and irrigation. Evelyn Merz of the Sims Bayou Coalition and overall coordinator of the Seedbank Project, and Sandy Marlin of the El Paso Energy environmental staff provided highly constructive comments on the drafts of this paper.

## REFERENCES

Arey, S. 1996. Conversation. Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Houston, Texas. 20 November.

Baker, W.B. 1996. Establishment of a prairie grass seedbank at Houston Lighting & Power's South Texas Project. Presented at The Coastal Prairie and Native Grasses Symposium. Houston, Texas, 24 October.

Bohnen, J.L. and A.M. Hanchek. 1992. Native grass and wildflower seed: an LCMR grant. In Proceedings of the Thirteenth North American Prairie Conference. Ontario, Canada, 6–9 August. pp. 239–241.

Campbell, J.A. 1996. Native Gulf coast prairie restoration project. Presented at The Coastal Prairie and Native Grasses Symposium. Houston, Texas, 24 October.

Cameron, G. 1996. Impact of exotic species on biodiversity of coastal prairie. Presented at The Coastal Prairie and Native Grasses Symposium. Houston, Texas, 24 October.

Chadwick, D.H. 1995. What good is a prairie? Audubon, 97(6): 36–46, 114–117.

Gould, F.W. 1975. The grasses of Texas. Texas A&M University Press, College Station, Texas, 653 pp.

Hatch, S.L., N.G. Gandhi, and L.E. Brown. 1990. Checklist of the vascular plants of Texas. Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas, 158 pp.

Koros, J.M. 1996. Restoring native coastal prairie grasses to Houston Bayous. Presented at The Coastal Prairie and Native Grasses Symposium. Houston, Texas, 24 October.

Olson, W.W. 1984. Large scale seed harvest of native tallgrass prairie. In: The Prairie: Past, Present and Future. Proceedings of the Ninth North American Prairie Conference. Moorhead, Minnesota, 29 July–1 August. pp. 213–215.

Smith, L. 1996. Rare and sensitive natural wetland plant communities of interior Louisiana. Louisiana Natural Heritage Program, Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana. 38 pp.

Texas Natural Heritage Program. 1993. Plant communities of Texas, series level. Texas Parks and Wildlife Department, Austin, Texas. 26 pp.

Texas Natural Resource Conservation Commission. 1996. Control of air emissions from visible emissions and particulate matter — outdoor burning — exception for prescribed burn. Texas Administrative Code Title 30, Part I, Chapter 111, Subchapter B, §111.211.

Wagner, M. and D. Riskind. 1992. Coastal prairie restoration on state parks. In: Abstracts of Papers Presented at the 27th Annual Meeting of Texas Chapter — The Wildlife Society. N. Koerth, ed. Texas Chapter of The Wildlife Society, Austin, Texas, p. 6.

---

### *BIOGRAPHICAL SKETCHES*

***Robert A. Honig***

*3803 Purdue Street, Houston, TX 77005, USA*

Robert A. Honig is an environmental consultant who was on the environmental staff of El Paso Energy (formerly Tenneco Energy) from 1982 to 1997 with responsibilities in pipeline construction and operations. Previously, he worked on the Eastern Energy and Land Use Team of the U.S. Fish and Wildlife Service in Leetown, West Virginia. He has a B.A. in Biology from the University of Pennsylvania and an M.S. in Zoology from Virginia Polytechnic Institute and State University. He also serves on the Board of Directors of the Katy Prairie Conservancy, a land trust focusing on prairie conservation.

***Gregory D. Wieland***

*Mercer Arboretum and Botanic Gardens, 22306 Aldine-Westfield Road, Humble, TX 77338, USA*

Gregory D. Wieland, Botanist at Mercer Arboretum and Botanic Gardens in Houston, Texas, manages the Gardens' conservation programs in cooperation with the Center for Plant Conservation. A particular interest is Texas Windmillgrass, a species targeted by the Seedbank Project. He is current president of the Mercer Chapter of the Native Plant Society of Texas. He has a Biology degree from the University of Alaska.

# Integrating Greenstripping into Right-of-Way Vegetation Management

**John C. Hogenbirk**

Greenstripping is the use of less-flammable plants to reduce fire hazard. Greenstripping has been used in the Intermountain region of the United States to reduce fire frequency and preserve plant diversity and shrub cover. Personnel in the Department of Biology at Laurentian University have investigated the feasibility of using greenstripping to reduce spring fires along railway right-of-ways in Ontario. Greenstripping has the potential to be less costly than current methods of fire prevention and control as well as the potential to be more effective, longer lasting and less damaging to the environment. Results could be applicable across North America and could help solve other vegetation management problems along right-of-ways. For example, greenstripping plants must persist for 10 years or more, and keep out highly flammable plants. Thus, it may be possible to use greenstripping to reduce tree invasion on right-of-ways. This could reduce herbicide use, brushing, and associated expenses. More than 250 species were evaluated for their ability to reduce fire hazard or tree invasion. Four forbs and over 25 shrubs are recommended for testing. A second group of approximately 30 species (forbs, grasses, ferns and shrubs) is recommended with some reservations. Planned experiments will investigate the efficacy of selected forbs and low-growing shrubs to reduce fire hazard and tree invasion along right-of-ways. Costs will be measured to permit comparison with other vegetation management methods.

*Keywords*: Integrated vegetation management, fire hazard, tree invasion, greenstripping, boreal, mixedwoods, Ontario

## INTRODUCTION

Greenstripping is the strategic sowing or planting of less-flammable plants to reduce fire hazard. Greenstripping has been used in Idaho to reduce fire frequency and help preserve plant diversity and shrub cover (Pellant 1990, 1994). To be effective, greenstripping plants must persist at the site for 5–10 years or more and keep out highly flammable plants and other undesirable species. Thus, it may be possible to use greenstripping to reduce tree invasion on right-of-ways and thus reduce herbicide use, brushing, and associated expenses.

Greenstripping could be integrated into existing vegetation management through the creation of stable vegetation communities (e.g., Niering and Egler 1955; Niering and Goodwin 1974; Bramble and Byrnes 1983; Niering, Dreyer, Egler, and Anderson 1986; Bramble, Byrnes, and Hutnik 1990, Bramble, Byrnes, Hutnik, and Liscinsky 1991). Stable vegetation communities show little change in plant species composition and abundance over time compared to other communities in which herbaceous plants are rapidly replaced by shrubs and then by trees in a typical successional sequence (e.g., Luken 1990).

Stable shrub communities and to a lesser extent stable herbaceous communities are capable of reducing tree invasion and growth (Niering, Dreyer, Egler and Anderson 1986; Bramble, Byrnes, and Hutnik 1990, Bramble, Byrnes, Hutnik, and Liscinsky 1991; Hill, Canham, and Wood 1995). The completeness and integrity of plant cover are important, but eventually stable communities will be invaded by undesirable species. Shading from adjacent trees, aging of the community, influx of seeds and suckers can allow undesirable species to invade (Dreyer and Niering 1986). Greenstripping has potential as one of several methods able to delay tree invasion by influencing colonization, species performance and disturbance regime (*sensu* Luken 1990).

The first objective of this paper is to briefly describe the railway fire regime and methods used by the Greenstripping Project to evaluate plant species for their potential to reduce fire hazard. The second objective is to describe methods to obtain information on species's ability to resist tree invasion. The third objective is to integrate this information to provide a final listing of recommended species.

## RAILWAY FIRES

Peak season for Ontario railway fires is in the spring, soon after snowmelt (Martell, Otukol, and Stocks 1987; Ontario Ministry of Natural Resources (OMNR) fire records). In contrast, July has the most person-caused fires (excluding railway fires) and lightning fires. Railway fires are common after snowmelt because the litter dries out and is easily ignited by sparks from passing trains.

Major causes for fires on class 1 track in the United States and Canada during 1987–1989 were: unknown, arson, and engine exhaust (Fitch and Westover 1991). OMNR records for the same three years identify brake shoe, engine exhaust and unknown as major causes of railway fires in Ontario. Major causes of fires on Ontario railways during 1985–1994 included brake shoes, engine exhaust, unknown, and rail grinding (OMNR fire records).

Prescribed burns along right-of-ways can be an effective method of controlling vegetation (Glover and Arner 1995) and reducing fire hazard (Chandler, Cheney, Thomas, Trabaud, and Williams 1983). However, many unplanned right-of-way fires in Ontario occur at the very start of the natural fire season. From an economic perspective, spring fires can be expensive because they often occur in remote areas and require that fire crews be hired earlier in the season. Reduction in the number of uncontrolled railway fires is desirable. Thus, the first goal of the Greenstripping Project was to evaluate plants for their ability to reduce fire hazard.

## EVALUATION METHODS

There are several thousand tree, shrub and herbaceous species in eastern North America (Gleason and Cronquist 1991) and complete autecological or synecological information is available for only a fraction of the total. There is little detailed information on flammability, particularly for species native to Ontario. In the first part of this paper the focus is on 49 herbaceous and low-growing shrub species common to right-of-ways in Ontario to get information on flammability and other essential characteristics (Table 1). Results of field and laboratory experiments were used to evaluate species, with detailed measurements of up to 15 species. Project personnel measured temperature-dependent growth using controlled environment chambers and measured growth in the field. In addition, project personnel measured fuel characteristics and time-to-ignition for plants collected during spring, the peak time for railway fires.

**Table 1. List of characteristics of the ideal greenstripping species for fire hazard reduction with emphasis on spring fires. The list was developed for right-of-ways in the boreal and mixedwood regions of Ontario. Some characteristics would help fulfill other vegetation management objectives. List requires modification if objective or ecoclimatic region are changed.**

In general, greenstripping plants should:
- reduce the probability of ignition throughout the year
- reduce the rate of fire spread throughout the year
- remain dominant at the site for 10+ years with no further maintenance
- create no additional environmental or safety hazards

In particular, greenstripping plants should:
- grow quickly in the spring to emerge from and then shade the litter
- maintain high moisture content throughout the growing season
- produce large-diameter stems and leaves
- produce dense tissues
- produce small quantities of dead standing crop
- produce small quantities of litter
- produce readily decomposed litter
- have slow drying and fast wetting litter
- have patchy spatial distribution of dead standing crop and litter
- have high silica-free ash content
- have low caloric value
- have small concentration of volatile waxes and oils
- be either herbaceous or low growing woody perennials
- out-compete other local plant species (especially trees, tall shrubs and noxious weeds)
- re-establish dominance after most disturbances
- be northern North American species, or
- exotic species, if used, should remain confined to greenstripping sites
- not harm humans and other wildlife, nor attract high numbers of wildlife
- control soil erosion
- be cost-effective (for chosen management objective, implementation and maintenance)

### Temperature-dependent growth

Greenstripping plants should grow quickly at low soil temperatures that occur during spring. Greenstripping plants should grow through the litter and then leaf-out to shade the litter and reduce fire hazard. In addition, greenstripping plants should produce small amounts of dead standing crop and litter.

Roots and rhizomes were collected in the spring of 1993 and 1994 from right-of-ways in the Regional Municipality of Sudbury, Ontario. Plants were grown in controlled environment chambers at the Ontario Institute of Forest Research in Sault Ste. Marie, Ontario.

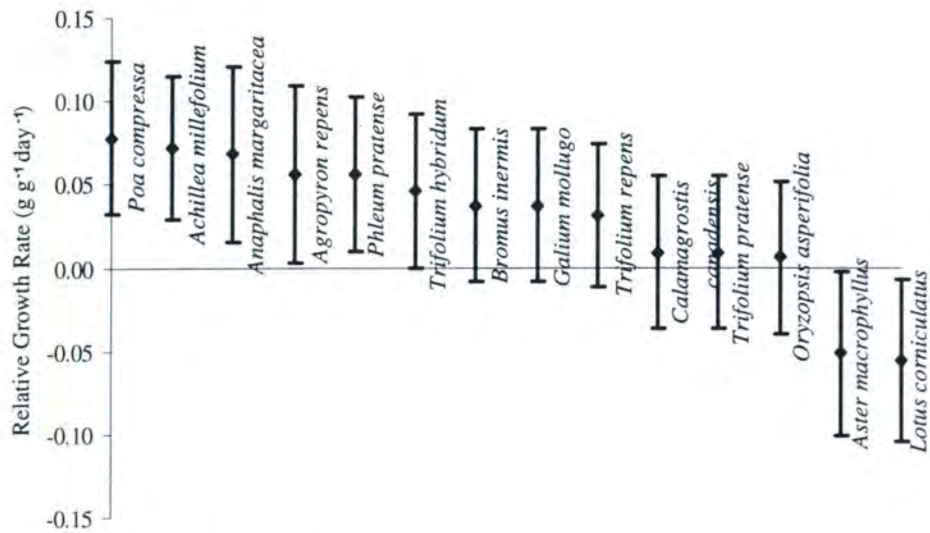



Fig. 1. Mean relative growth rate (g $g^{-1}$ $day^{-1}$) ($n$ = 6–12 per harvest) and 95% comparison limits of above ground dry tissue of 14 herbaceous species grown at 8°C. Three species, *Oryzopsis asperifolia*, *Achillea millefolium* and *Lotus corniculatus*, were grown for 14 days in sand in 1993; remaining species were grown for 16 days in peat-vermiculite mixture in 1994.

Three species, *Achillea millefolium* L., *Lotus corniculatus* L., and *Oryzopsis asperifolia* Michaux, were grown in sand in 1993. The remaining eleven species were grown in 1994 in a peat-vermiculite mix (2:1, by volume). Species nomenclature from Dore and McNeill (1980) for grasses, Soper and Heimburger (1982) for shrubs and Gleason and Cronquist (1991) for other species. All plants were watered and fertilized with a hydroponic solution (Plant Products 7–11–27 and 15.5–0–0, with micronutrients). Plants were grown at 8, 12 and 16°C for 21–30 days. Humidity was greater than 65%, with 15.5 hours of fluorescent lighting (photosynthetically active radiation, 235 µmol $m^{-2}$ $s^{-1}$, at 1 m distance from lights). Plant height, live and dead dry weights were measured for 6–12 plants per harvest. Dry weights for all experiments were obtained after 48 hours at 80°C. Percent live tissue and relative growth rate (RGR) with 95% comparison limits were calculated (Venus and Causton 1979). Comparison limits are preferred over confidence limits when replication is unequal (Sokal and Rohlf 1995). Results are summarized by above-ground RGR after 14–16 days at 8°C.

The five species with highest mean aboveground RGR after 14–16 days of growth at 8°C were: *Poa compressa* L., *Achillea millefolium*, *Anaphalis margaritacea* (L.) Benth & Hook., *Agropyron repens* (L.) Beauv. and *Phleum pratense* L. (Fig. 1). *Poa compressa* and *Agropyron repens* also had increasing percentage live aboveground tissue during the experiments while *Phleum pratense* had decreasing percentage live tissue (Hogenbirk 1996a). *Achillea millefolium* and *Anaphalis margaritacea* had consistently high percentage live tissue. Unfortunately, both herbs are weedy species (Frankton and Mulligan 1987) and the grasses are exotic species that pose problems for railway vegetation management (Polster and Landry 1995).

**Field surveys**

Potential greenstripping species should be 1–2 m high and extend shade over a large area. In addition, potential greenstripping species should dominate the area, have low amounts of litter and high percentage live tissue.

Quadrats were set up around target plants in May–June 1993 at six railway right-of-ways located outside of the semi-barren lands in the Regional Municipality of Sudbury. Quadrats were monitored each month for five consecutive months. Total quadrat biomass and litter, height, area, live and dead tissue dry weight were measured and percent live tissue, percent shade, and area covered per unit biomass were calculated for 41 plant species. Non-destructive measurements were made before harvesting. One quadrat was harvested per species per site per date. Statistical analyses were not conducted because not all species could be located at all sites. Instead, means and standard deviations were calculated and biologically significant differences were looked for within the limits of the study design.

Twelve of 41 species had greater spring height, high area covered per unit mass dry weight and high percent shade. Five species, *Aster umbellatus* L., *Hieracium floribundum* Wimmer and Grab., *Melilotus alba* L., *Rubus canadensis* L. and *Rumex acetosella* L., have several desirable attributes and few undesirable attributes (Hogenbirk 1996a). A number of rapidly growing species, predominately grasses (e.g., *Agropyron repens*, *Bromus inermis* Leysser, and *Calamagrostis canadensis* (Michaux) Beauv.) but including *Achillea millefolium* and *Pteridium aquilinum* (L.) Kuhn, are unsuitable as greenstripping species because of high potential fire hazard or weedy nature or both. *Melilotus alba* may have potential as a starter crop in poor soils while other introduced species such as *Hieracium floribundum* and *Rumex acetosella* may indicate sites of low fire hazard and poor tree growth.

## Flammability testing

*Fuel characteristics*

There are a number of characteristics related to flammability and fire behaviour (e.g., Chandler, Cheney, Thomas, Trabaud, and Williams 1983). The relative importance of these characteristics in predicting ignitability is unknown (Hogenbirk and Sarrazin-Delay 1995). Physical and chemical fuel characteristics were measured for live and dead stems of 20 plant species and species were ranked by potential ignitability.

Plant samples were collected from the field in June 1994 and collected in May–June 1995 from plants grown in a common garden. Samples were sorted into live or dead, stem or leaf tissue, and dried at 80°C for 48 hours. Physical fuel characteristics (stem dry weight and diameter) were measured on up to 25 stems per each 1 mm diameter stem class. Species means were calculated by multiplying the stem class average by the proportion of biomass in that stem class. Chemical fuel characteristics (ash, silica-free ash and energy content) were measured using standard methods (Allen, Grimshaw, and Rowland 1986; ASTM 1993). Samples were ground to pass through a 1 mm mesh. Measurements were made on samples from individual stem classes or from pooled classes. Plant species were then ranked based on these fuel characteristics to estimate potential ignitability (Hogenbirk and Sarrazin-Delay 1995).

*Anaphalis margaritacea*, *Trifolium hybridum* L. and *Aster macrophyllus* L. had the lowest mean rank (low ignitability) for physical and chemical fuel characteristics (ranks in Table 2, observed values in Table 3). *Poa compressa*, *Lotus corniculatus* and *Phleum pratense* had the highest mean rank (high ignitability). *Anaphalis margaritacea*, *Aster macrophyllus* and *Trifolium hybridum* had the lowest mean rank for the physical fuel characteristics. *Poa compressa*, *Lotus corniculatus*, *Vicia villosa* Roth. and *Galium mollugo* L. had the highest mean rank. For chemical fuel characteristics, *Galium mollugo*, *Anaphalis margaritacea* and *Trifolium repens* L. had the lowest mean rank while *Phleum pratense*, *Bromus inermis* and *Aster macrophyllus* had the highest rank.

*Time-to-Ignition*

Greenstripping plants should take longer to ignite. Time-to-ignition was measured for sixteen plant species using a modified muffle furnace and data acquisition system (Hogenbirk 1996b). Time-to-ignition was regressed against fuel characteristics to determine the relative importance of fuel characteristics. Regression equations were used to evaluate additional species.

*Aster macrophyllus* had the longest time-to-ignition for dead stems, thus making it the least ignitable of the species tested (Table 3). *Anaphalis margaritacea* and *Phleum pratense* also had relatively long time-to-ignition. *Vicia villosa*, *Poa compressa* and *Coronilla varia* L. had the shortest time-to-ignition. Similar trends were observed within individual stem classes (Hogenbirk 1996b).

Stem density was consistently an important predictor of time-to-ignition for dead herbaceous stems (Hogenbirk 1996a,b). Radius, surface area to volume ratio and, to a lesser extent, moisture were the next best predictors. Time-to-ignition increased with increasing

**Table 2. Mean ranks for herbaceous plant species based physical and chemical fuel characteristics and rank for time-to-ignition are given. Species were ranked from 1 to 15 with a rank of 1 given to the species with the fuel characteristics value associated with low ignitability. Species nomenclature based on Dore and McNeill (1980) for grasses, Soper and Heimburger (1982) for shrubs and Gleason and Cronquist (1991) for remaining species.**

| Species | Plant grown from root or seed | Mean Rank | | | Rank |
|---|---|---|---|---|---|
| | | Physical & chemical | Physical only | Chemical only | Time-to-ignition |
| *Agropyron repens* (L.) Beauv. | Root | 11.5 | 10 | 11 | 9 |
| *Anaphalis margaritacea* (L.) Benth & Hook. | Root | 1 | 2 | 2 | 2 |
| *Aster macrophyllus* L. | Root | 3 | 1 | 13 | 1 |
| *Bromus inermis* Leysser | Root | 11.5 | 7 | 14 | 4 |
| *Calamagrostis canadensis* (Michaux) Beauv. | Root | 8 | 9 | 8 | 5 |
| *Coronilla varia* L. | Seed | 10 | 8 | 12 | 13 |
| *Galium mollugo* L. | Root | 6.5 | 12.5 | 1 | 10 |
| *Lotus corniculatus* L. | Seed | 14 | 14 | 6 | 12 |
| *Medicago sativa* L. | Seed | 6.5 | 4.5 | 10 | 6 |
| *Phleum pratense* L. | Root | 13 | 6 | 15 | 3 |
| *Poa compressa* L. | Root | 15 | 15 | 9 | 14.5 |
| *Trifolium hybridum* L. | Root | 2 | 3 | 4.5 | 8 |
| *Trifolium pratense* L. | Seed | 5 | 4.5 | 7 | 7 |
| *Trifolium repens* L. | Root | 4 | 11 | 3 | 11 |
| *Vicia villosa* Roth. | Seed | 9 | 12.5 | 4.5 | 14.5 |

**Table 3. Time-to-ignition and fuel characteristics for dead stems of 15 herbaceous species grown in a common garden in Sudbury, Ontario. Physical characteristics and time-to-ignition were measured for 5–15 stems from each 1 mm diameter class and multiplied by the proportion of biomass in that stem class to provide species means. Surface area to volume ratio (SA:V) was calculated for 1 cm long stems. Chemical characteristics were measured for pooled samples.**

| Species | Time to ignition | | Physical characteristics | | | Chemical characteristics | | |
|---|---|---|---|---|---|---|---|---|
| | Time (s) | Moisture (%) | Radius (cm) | Density (g/cm) | SA:V ($cm^{-1}$) | Ash (%) | Silica-free ash (%) | Energy (J/g) |
| *Agropyron repens* (L.) Beauv. | 3.0 | 23.2 | 0.060 | 0.262 | 29.5 | 4.8 | 1.5 | |
| *Anaphalis margaritacea* (L.) Benth & Hook. | 5.4 | 23.3 | 0.082 | 0.349 | 24.6 | 10.7 | 4.9 | |
| *Aster macrophyllus* L. | 9.5 | 23.1 | 0.142 | 0.374 | 16.4 | 2.3 | 2.0 | 19157 |
| *Bromus inermis* Leysser | 4.2 | 19.8 | 0.096 | 0.216 | 19.9 | 4.3 | 1.4 | 18905 |
| *Calamagrostis canadensis* (Michaux) Beauv. | 4.1 | 21.5 | 0.062 | 0.329 | 28.7 | 9.7 | 2.2 | |
| *Coronilla varia* L. | 2.3 | 23.0 | 0.086 | 0.165 | 22.6 | 3.5 | 2.3 | 19475 |
| *Galium mollugo* L. | 2.9 | 19.7 | 0.056 | 0.354 | 34.0 | 9.1 | 6.1 | 18403 |
| *Lotus corniculatus* L. | 2.4 | 18.6 | 0.039 | 0.358 | 44.8 | 5.2 | 3.1 | |
| *Medicago sativa* L. | 3.9 | 25.2 | 0.064 | 0.278 | 28.9 | 4.4 | 2.9 | 20032 |
| *Phleum pratense* L. | 4.5 | 20.8 | 0.089 | 0.262 | 22.1 | 2.5 | 1.0 | 19240 |
| *Poa compressa* L. | 2.1 | 20.9 | 0.057 | 0.171 | 30.1 | 5.9 | 1.8 | |
| *Trifolium hybridum* L. | 3.3 | 24.7 | 0.106 | 0.151 | 18.8 | 6.5 | 4.2 | |
| *Trifolium pratense* L. | 3.4 | 23.0 | 0.124 | 0.172 | 22.2 | 4.7 | 3.6 | 19624 |
| *Trifolium repens* L. | 2.5 | 22.2 | 0.074 | 0.197 | 25.3 | 8.6 | 5.4 | 19149 |
| *Vicia villosa* Roth. | 2.1 | 22.8 | 0.051 | 0.274 | 39.7 | 7.1 | 4.1 | |

density, radius and moisture, and with decreasing surface area to volume ratio. Preliminary analyses suggest that chemical characteristics such as total ash, silica-free ash and energy content were not important predictors of time-to-ignition. It is hypothesized that the evaluation of herbaceous stem ignitability can be based on physical fuel characteristics derived from stem weight and diameter.

## Species with potential to reduce fire hazard

The fire hazard ranking of forty-nine herbaceous and low-growing shrub species (Table 4) used all collected data. No single species had all the desired characteristics. Six species were selected that had one or more of the following: high stem density, high percent live tissue and good height.

*Achillea millefolium*, *Aster macrophyllus* and *Aster umbellatus* are recommended for use as greenstripping species with the following caveats. *Achillea millefolium* may be too weedy (Frankton and Mulligan 1987). *Aster macrophyllus* is best suited to low-growing vegetation (<20 cm tall) and may need to be planted with a species with high spring growth rate. *Aster umbellatus* is probably best suited to moist habitats. The presence of these species should indicate low fire hazard. The spread of these species could be encouraged along right-of-ways, although potential conflict with forestry and agriculture should be noted.

Two commercially available species, *Trifolium pratense* and *T. repens*, are recommended with the following cautions. *Trifolium pratense* can have poor persistence (Robinson, Clare, and Leahy 1992) and may be best used as a starter crop. *Trifolium pratense* can outcompete other legumes in mixtures so choice of companion species is important. *Trifolium repens* is best suited to low-growing vegetation. Taller varieties of *T. repens* may have potential as greenstripping plants.

*Rubus canadensis*, smooth blackberry, is recommended with one caution. This deciduous shrub has high density, good height, high percent live tissue and intermediate percent shade which indicate low ignitability. Time-to-ignition, however, was not directly measured for smooth blackberry and thus its low-ignitability rank is tentative.

## Resistance to tree invasion

Published information and consultations with experts were used to estimate the potential of over 250 herb and shrub species to resist tree invasion. Results from Soper and Heimburger (1982) were used to select shrubs capable of forming closed stands on mesic to xeric habitats. Additional information on all species was obtained from autecological summaries (Hardy BBT Ltd. 1989; Haeussler, Coates, and Mather 1990; Thomas 1990; Buse and Bell 1992; Louter, Kershaw, and Gordon 1993; Bentley and Pinto 1994; Arnup, Dowsley, Buse, and Bell 1995), numerous scientific articles (see bibliographies in Abrahamson, Nowak, Charlton, and Snyder 1992, and Hogenbirk 1996b) and reviews (Suffling 1979; Brown 1989). This information was combined with results of the author's experiments to select four herbs and over 25 shrubs for the potential to reduce fire hazard or tree invasion, or both.

**Table 4. Species evaluated for potential to reduce fire hazard. Low-flammability species indicated by asterisk after name. This list should be considered a first approximation for fire hazard reduction in boreal and mixedwood regions of Ontario.**

| Species | Common name | Growth form |
|---|---|---|
| *Achillea millefolium* L.* | yarrow | forb |
| *Agropyron repens* (L.) Beauv. | quack grass | grass |
| *Agrostis gigantea* Roth | redtop | grass |
| *Anaphalis margaritacea* (L.) Benth & Hook. | pearly everlasting | forb |
| *Antennaria neglecta* Greene | pussy toes | forb |
| *Apocynum androsaemifolium* L. | spreading dogbane | forb |
| *Arctostaphylos uva ursi* (L.) Spreng. | bearberry | shrub |
| *Aster macrophyllus* L.* | large-leaved aster | forb |
| *Aster umbellatus* L.* | flat top aster | forb |
| *Bromus inermis* Leysser | smooth brome | grass |
| *Calamagrostis canadensis* (Michaux) Beauv. | bluejoint | grass |
| *Chrysanthemum leucanthemum* L. | oxe eye daisy | forb |
| *Clintonia borealis* (Ait.) Raf. | blue-beard lily | forb |
| *Coronilla varia* L. | crown vetch | legume |
| *Danthonia spicata* (L.) Beauv. | poverty oat grass | grass |
| *Deschampsia flexuosa* (L.) Trin. | crinkled hair grass | grass |
| *Echium vulgare* L. | blueweed | forb |
| *Festuca rubra* L. | red fescue | grass |
| *Fragaria virginiana* Duchesne | strawberry | forb |
| *Galium mollugo* L. | wild madder | forb |
| *Glyceria canadensis* (Michaux) Trin. | rattlesnake manna grass | grass |
| *Hieracium aurantiacum* L. | orange hawkweed | forb |
| *Hieracium floribundum* Wimmer & Grab. | king devil hawkweed | forb |
| *Hieracium sp.* | hawkweed | forb |
| *Kalmia angustifolia* L. | sheep laurel | shrub |
| *Lactuca serriola* L. | prickly lettuce | forb |
| *Lathyrus maritimus* (L.) Bigelow | beach pea | legume |
| *Ledum groenlandicum* Oeder | Labrador tea | shrub |
| *Lolium perenne* L. | perennial ryegrass | grass |
| *Lotus corniculatus* L. | bird's foot trefoil | legume |
| *Maianthemum canadense* Desf. | Canada mayflower | forb |
| *Medicago sativa* L. | alfalfa | legume |
| *Melilotus alba* Desr. | white sweet clover | legume |
| *Oryzopsis asperifolia* Michaux | winter (rice) grass | grass |
| *Phleum pratense* L. | timothy | grass |
| *Poa compressa* L. | Canada bluegrass | grass |
| *Pteridium aquilinum* (L.) Kuhn. | eastern bracken fern | fern |
| *Ranunculus acris* L. | tall buttercup | forb |
| *Rubus canadensis* L.* | smooth blackberry | shrub |
| *Rumex acetosella* L. | sheep sorrel | forb |
| *Solidago uliginosa* Nutt. | bog goldenrod | forb |
| *Taraxacum officinale* Weber. | dandelion | forb |
| *Trifolium hybridum* L. | alsike clover | legume |
| *Trifolium pratense* L* | red clover | legume |
| *Trifolium repens* L.* | white clover | legume |
| *Vaccinium angustifolium* Ait. | low sweet blueberry | shrub |
| *Verbascum thapsus* L. | mullein | forb |
| *Veronica* sp. | speedwells | forb |
| *Vicia cracca* L. | cow or tufted vetch | legume |
| *Vicia villosa* Roth. | hairy vetch | legume |
| *Viola papilionacea* Pursh. | common blue violet | forb |

**Table 5. Species recommended for potential to reduce tree invasion, or fire hazard, or both. Unknown potential indicated by question mark. Tree invasion includes establishment and growth. This list should be considered a first approximation: additional testing is required.**

| Species Latin name | | Common name | Resistance to tree invasion? | Reduce fire hazard? | Comments |
|---|---|---|---|---|---|
| **Recommended** | | | | | |
| Forbs | *Aster macrophyllus* L. | big-leaved aster | Yes | Yes | |
| | *Aster umbellatus* Mill. | flat topped aster | Yes | ? | |
| | *Epilobium angustifolium* L. | fireweed | Yes | Yes | |
| | *Solidago* spp. | goldenrods | Yes | ? | |
| Shrubs | *Amelanchier* spp. | serviceberries | Yes | ? | |
| | *Betula pumila* L. | dwarf birch | Yes | ? | |
| | *Chamaedaphne calyculata* (L.) Moench | leatherleaf | Yes | ? | |
| | *Cornus stolonifera* Michx. | red osier dogwood | Yes | ? | |
| | *Diervilla lonicera* Mill. | bush honeysuckle | Yes? | ? | |
| | *Lonicera* spp. | honeysuckles | Yes | ? | |
| | *Rhus aromatica* Ait. | fragrant sumach | ? | ? | |
| | *Rhus glabra* L. | smooth sumach | ? | ? | |
| | *Rhus typhina* L. | staghorn sumach | Yes | ? | |
| | *Ribes* spp. | currants | Yes | ? | Shrub complex |
| | *Rosa* spp. | roses | Yes | ? | Shrub complex |
| | *Rubus canadensis* L. | blackberry | ? | Yes? | |
| | *Rubus hispidus* L. | swamp dewberry | Yes | ? | |
| | *Rubus idaeus* L. | wild red raspberry | Yes | ? | |
| | *Rubus occidentalis* L. | black raspberry | ? | ? | |
| | *Rubus odoratus* L. | purple-flowering raspberry | ? | ? | |
| | *Rubus parviflorus* Nutt. | thimbleberry | Yes | ? | |
| | *Rubus pubescens* Raf. | dwarf raspberry | ? | ? | |
| | *Salix cordata* Michx. | heart-leaved willow | ? | ? | |
| | *Salix exigua* Nutt. | sandbar willow | ? | ? | |
| | *Salix petiolaris* J. E. Sm. | slender willow | Yes | ? | |
| | *Symphoricarpos albus* (L.) Blake | snowberry | Yes? | ? | |
| | *Symphoricarpos occidentalis* Hook | wolfberry | Yes | ? | |
| | *Viburnum lentago* L. | nannyberry | Yes | ? | |
| **Recommended with reservations** | | | | | |
| Forbs | *Achillea millefolium* L. | common yarrow | Poor | Yes | Weed |
| | *Anaphalis margaritacea* (L.) Benth & Hook | pearly everlasting | ? | Yes | Weed |
| | *Coronilla varia* L. | crown vetch | Yes | No | fixes nitrogen |
| | *Trifolium hybridum* L. | alsike clover | Yes? | Variable | fixes nitrogen |
| | *Trifolium pratense* L. | red clover | Poor | Variable | fixes nitrogen |
| | *Trifolium repens* L. | white clover | Poor | Variable | fixes nitrogen |
| Grasses | *Calamagrostis canadensis* (Michaux) Beauv. | Canada blue joint | Yes | No | |
| | *Dactylis glomerata* L. | orchard grass | Yes | No? | |
| | *Festuca arundinacea* Schreber | tall fescue | Yes | No? | |
| | *Phalaris arundinacea* L. | reed canary grass | Yes | No? | |
| Ferns | *Dennstaedtia punctilobula* (Michx.) Moore | hayscented fern | Yes | ? | Frost-killed |
| | *Pteridium aquilinum* (L.) Kuhn. | bracken fern | Yes | No | Frost-killed |
| | *Thelypteris noveboracensis* (L.) Nieuwl. | New York fern | Yes | ? | Frost-killed |
| Shrubs | *Alnus* spp. | alders | Yes? | ? | Fixes nitrogen |
| | *Arctostaphylos uva-ursi* (L.) Spreng. | bearberry | Yes? | ? | Low habit |
| | *Comptonia peregrina* (L.) Coult. | sweet-fern | Poor | ? | Weed |
| | *Corylus* spp. | hazel(nut) | Yes | ? | |
| | *Elaeagnus commutata* Bernh. | wolf-willow | ? | ? | Fixes nitrogen |
| | *Juniperus* spp. | junipers | ? | No | |
| | *Kalmia* spp. | laurel | Yes | No | |
| | *Ledum groenlandicum* Oeder | Labrador tea | Yes | No | |
| | *Sambucus pubens* Michx. | red-berried elder | Yes? | ? | |
| | *Shepherdia canadensis* (L.) Nutt. | buffalo berry | ? | ? | Fixes nitrogen |
| | *Spirea* spp. | meadowsweet | ? | ? | |
| | *Thuja occidentalis* L. | cedar | Yes? | ? | Needs pruning |
| | *Vaccinium* spp. | blue-, dil-, and cran-berries | Yes | No | |
| | *Zanthoxylum americanum* Mill. | prickly ash | Yes | ? | Unpalatable |

## SPECIES WITH POTENTIAL TO REDUCE FIRE HAZARD AND TREE INVASION

### Herbaceous Species

Recommended herbaceous species include: *Aster macrophyllus*, *Aster umbellatus*, *Epilobium angustifolium* L. and *Solidago* spp. (Table 5). Research by Greenstripping Project personnel suggested that *Aster macrophyllus* has the potential to reduce fire hazard. Moisture content was high throughout the growing season in Minnesota and Michigan (Loomis, Roussopoulos, and Blank 1979; Loomis and Blank 1980). In forest clearings *A. macrophyllus* can form dense patches that pose serious competition to tree seedlings (Buse and Bell 1992; Arnup, Dowsley, Buse, and Bell 1995). The seed is easily collected and germinated, and the plant is readily propagated from rhizomes. *Aster macrophyllus* could be used in low-growing vegetation with other species that have rapid spring growth.

The ability of *Aster umbellatus* (flat topped aster) to reduce fire hazard is unknown but may be unimportant because *Aster umbellatus* is found in moist areas (Gleason and Cronquist 1991) where fire hazard is low. Shoot and root washings of *Aster umbellatus* inhibited black cherry (*Prunus serotina*) germination and seedling growth (Horsley 1977). In addition, the height and shade cast by *Aster umbellatus* may reduce tree growth in moist areas. Work along right-of-ways in Québec suggest that *Aster* spp. may reduce tree vitality (Consortium F.R.D.F. - Sauger 1992, as cited in Séguin 1995).

*Epilobium angustifolium* (fireweed) may be able to reduce fire hazard and tree invasion. Fireweed had the lowest flammability rating of twelve arctic species examined by Sylvester and Wein (1981) with little litter accumulation. Fireweed invades after disturbance by seed and vegetative spread, reaching peak dominance in 3–5 years and declining thereafter, although some patches may persist up to 20 years (Haeussler, Coates, and Mather 1990). Fireweed competes for water and nutrients, and may encourage snow press (Arnup, Dowsley, Buse, and Bell 1995). Snow press occurs when the accumulated snow flattens tree seedlings. The flattened seedlings may remain below competing vegetation thereby decreasing growth and increasing susceptibility to disease. Snow press can be a major cause of tree mortality (Haeussler, Coates, and Mather 1990).

Fireweed, however, may suppress shrub growth and thereby allow conifers to dominate in later years (Haeussler, Coates, and Mather 1990). Soil temperatures at 10 cm depth and light levels (photosynthetically active radiation) at soil surface were significantly lower in fireweed dominated plots compared to bare ground. However, soil temperature and light in fireweed plots were significantly higher than in *Rubus spectabilis* Pursh, *Alnus rubra* Bong. (Balisky and Burton 1993) and *Calamagrostis canadensis* dominated plots (Hogg and Lieffers 1991).

Deliberate sowing of easily collected fireweed seed or planting of pseudorhizomes may be feasible. Plants produce attractive purple flowers each year and could be used to enhance right-of-way aesthetics. Fireweed attracts nectar feeders, provides cover for small animals and may provide food for larger mammals (Haeussler, Coates, and Mather 1990). Fireweed has good potential to reduce fire hazard and tree invasion along right-of-ways.

*Solidago* spp. may have the potential to reduce tree invasion (Consortium F.R.D.F. — Sauger 1992, as cited in Séguin 1995). *Solidago canadensis* L. can form colonies and may inhibit tree seed germination through allelopathy (Louter, Kershaw, and Gordon 1993). *Solidago rugosa* Miller and *S. graminifolia* (*Euthamia graminifolia* (L.) Nutt.) are considered highly resistant to tree invasion along right-of-ways in north central United States (Bramble, Byrnes and Hutnik 1990). Flammability of *Solidago* spp. is unknown.

### Shrub species

Recommended shrub species include: *Amelanchier* spp., *Betula pumila* L., *Chamaedaphne calyculata* (L.) Moench, *Cornus stolonifera* Michx., *Diervilla lonicera* Mill., *Lonicera* spp., *Rhus* spp., *Ribes* spp., *Rosa* spp., *Rubus* spp., *Salix* spp., *Symphoricarpos* spp., and *Viburnum* spp. Several shrubs provide cover or fruit that attracts humans and wildlife and thus may be unsuitable for transportation right-of-ways.

*Amelanchier* spp., *Betula pumila*, *Chamaedaphne calyculata*, *Diervilla lonicera*, and *Lonicera* spp., are low-growing, thicket forming shrubs (Soper and Heimburger 1982) with the ability to reduce tree invasion (Arnup, Dowsley, Buse, and Bell 1995). Allelopathy is suspected for *Chamaedaphne calyculata* and *Lonicera villosa* (Michx.) R. & S. (Arnup, Dowsley, Buse, and Bell 1995).

*Cornus oblique* Raf. (silky dogwood), *C. racemosa* Lam. (gray dogwood), *C. rugosa* Lam. (round-leaved dogwood) and *C. stolonifera* (red osier dogwood), are low-growing, thicket forming shrubs (Soper and Heimburger 1982) that are major competitors of tree seedlings and can resist tree invasion (Meilleur, Véronneau, and Bouchard 1994; Berkowitz and Canham 1995; Canham, Hill, Berkowitz, and Ostfeld 1995; Hill, Canham, and Wood 1995). Red osier dogwood was recommended by Thomas (1990) as a weed-resistant ground cover. Red osier dogwood has been propagated by layering and rooted cuttings in experimental studies along Québec right-of-ways (Meilleur, Véronneau, and Bouchard 1992, as cited in Séguin 1995). Red osier dogwood is perhaps the most widespread in geography and habitat and is strongly recommended for testing.

*Rhus aromatica* Ait. (fragrant sumach), *R. glabra* L. (smooth sumach) and *R. typhina* L. (staghorn sumach) are low to tall growing, thicket-forming shrubs (Soper and Heimburger 1982). Staghorn sumach has some potential to reduce tree invasion (Werner and Harbeck 1982; Meilleur, Véronneau, and Bouchard 1994). Propagation by cuttings may be poor on sandy soils

(Meilleur, Véronneau, and Bouchard 1992, as cited in Séguin 1995). In contrast, Petranka and McPherson (1979) found that *R. copallina* Engler (dwarf sumach) increased tree invasion and thus ranked last out of 177 species in ability to inhibit tree growth (Brown 1989).

*Ribes* spp. (currants and gooseberries) and *Rosa* spp. (roses) are low-growing shrubs (Soper and Heimburger 1982) that, as part of a shrub complex in British Columbia, can shade out young conifers (Haeussler, Coates, and Mather 1990). Some *Ribes* species serve as alternative hosts of white pine blister rust (Arnup, Dowsley, Buse, and Bell 1995). Some *Rosa* species may be allelopathic (Haeussler, Coates, and Mather 1990). *Rosa acicularis* Lindl. (prickly wild rose) and *R. woodsii* Lindl. (common wild rose, woods rose) are used in reclamation (Hardy BBT Ltd. 1989). *Rosa woodsii* and other species (some not native to Canada) were recommended by Thomas (1990) as weed-resistant ground cover.

There are several species of *Rubus* that have the potential to reduce tree invasion although the evidence is variable (Shribbs and Skroach 1986; Bramble, Byrnes, and Hutnik 1990; Meilleur, Véronneau, and Bouchard 1994). *Rubus allegheniensis* Porter was recommended by Suffling (1979). Canham, Hill, Berkowitz, and Ostfeld (1995) found that *R. allegheniensis* had very high resistance to tree invasion in New York state. In contrast, Bramble, Byrnes, and Hutnik (1990) and Meilleur, Véronneau, and Bouchard (1994) found that it did not reduce tree invasion along right-of-ways in north central United States and Québec, respectively.

*Rubus canadensis* (smooth blackberry) has the potential to reduce fire hazard based on high stem density, dominance, dense shade and little litter (Hogenbirk 1996a). *Rubus canadensis* may be well-adapted to open right-of-ways and testing is strongly recommended.

*Rubus flagellaris* Willd. (northern dewberry) is a prostrate shrub of dry areas (Soper and Heimburger 1982). In communities with *Solidago* spp. (primarily *Solidago rugosa*), *Rubus flagellaris* was found to have very high resistance to red maple invasion but very low resistance to white ash invasion and very low overall resistance to tree invasion (Canham, Hill, Berkowitz, and Ostfeld 1995).

*Rubus hispidus* L. (swamp dewberry) is a low-growing, trailing shrub of wet areas (Soper and Heimburger 1982). Dense patches of *Rubus hispidus* are highly resistant to tree invasion (Bramble, Byrnes, and Hutnik 1990). Scattered shrubs, however, are often surrounded by vegetation with low resistance (Bramble, Byrnes, and Hutnik 1990). The use of a compatible herbaceous greenstripping species might improve overall resistance in scattered shrublands.

*Rubus idaeus* L. (wild red raspberry) is a low-growing thicket-forming shrub (Soper and Heimburger 1982) capable of rapid growth (Hardy BBT Ltd. 1989) and is a major competitor of tree seedlings (Arnup, Dowsley, Buse and Bell 1995; Lautenschlager 1995). *Rubus idaeus* was ranked 35 out of 177 in its ability to interfere with tree growth (Brown 1989). Data from Québec suggest that it reduces tree invasion (Meilleur, Véronneau, and Bouchard 1994) although Ruel (1992) found that balsam fir growth was only slightly reduced. *Rubus idaeus* is common to northern Ontario railways (Polster and Landry 1995). *Rubus idaeus* is well suited for right-of-ways and testing is highly recommended.

*Rubus occidentalis* L. and *R. odoratus* L. have the potential to dominate an area and are common in southern Ontario (Soper and Heimburger 1982). *Rubus parviflorus* Nutt. can form thickets and is an important competitor in BC (Haeussler, Coates, and Mather 1990), but in Ontario it is restricted to the shores of Lake Superior (Soper and Heimburger 1982). *Rubus odoratus* and *R. parviflorus* were recommended by Thomas (1990) for ground cover. *Rubus pubescens* Raf. is a low-growing, trailing shrub that is widely distributed in Ontario (Soper and Heimburger 1982). The ability of these species to reduce tree invasion and fire hazard must be determined.

*Salix* spp. (willows), are low to tall shrubs common to areas with high water tables in the spring but occasionally found on drier sites (Soper and Heimburger 1982). Some species have the potential to compete with tree seedlings and damage tree seedlings through snow press or by providing cover for herbivores (Louter, Kershaw, and Gordon 1993). Conversely, some willows serve as nurse crops for shade-tolerant conifers (Louter, Kershaw, and Gordon 1993). Many willow species are used in reclamation (Hardy BBT Ltd. 1989).

*Salix cordata* Michx. (heart-leaved willow) and *S. exigua* Nutt. (sandbar willow) are low-growing, thicket-forming shrubs common to riverbanks (Soper and Heimburger 1982). *Salix petiolaris* J. E. Sm. (slender willow) is a low to medium shrub that has some potential to reduce tree invasion (Meilleur, Véronneau, and Bouchard 1994). *Salix petiolaris* responded poorly to layering and cutting back (but note that few test species responded well to cutting back, Meilleur, Véronneau, and Bouchard 1994). Very little is known about ability to reduce fire hazard. The rapid growth of many willow species and their ability to form dense colonies strongly suggest that selected species be investigated for use in greenstripping.

*Symphoricarpos albus* (L.) Blake (snowberry) and *S. occidentalis* Hook. (wolfberry), are low-growing, thicket-forming shrubs (Soper and Heimburger 1982). There are concerns about snowberry even though it was recommended as ground cover by Thomas (1990). Its canopy may be too sparse to shade out tree seedlings and allelopathy has been demonstrated in the lab but not in the field (Haeussler, Coates, and Mather 1990). Wolfberry is strongly competitive with grasses and is used in reclamation (Hardy BBT Ltd. 1989). Both snowberry and wolfberry are well-suited to right-of-ways and testing is recommended.

*Viburnum lentago* L. (nannyberry) is a tall, thicket-forming shrub (Soper and Heimburger 1982). One thicket has resisted tree invasion for over 55 years

(Niering, Dreyer, Egler, and Anderson 1986). Meilleur, Véronneau and Bouchard (1994) were unable to evaluate its potential to reduce tree invasion along Québec right-of-ways. Other *Viburnum* species are capable of forming stable thickets but flammability is largely unknown.

*Flammable* shrub species with good potential to reduce tree invasion include: *Juniperus* spp., *Kalmia* spp., *Ledum groenlandicum* Oeder and *Vaccinium* spp. There is good evidence that these species are flammable. For example, *Kalmia* spp., and *Ledum* spp. *Vaccinium* spp. are readily burnt every 2–3 years in blueberry fields (Hall, Jackson, and Everett 1973). There is also good evidence that these shrubs can reduce tree invasion although performance is variable (Bramble, Byrnes, and Hutnik 1990; Berkowitz and Canham 1995; Canham, Hill, Berkowitz, and Ostfield 1995; Hill, Canham, and Wood 1995; Mallik 1993; Meilleur, Véronneau, and Bouchard 1994; Pound and Egler 1953). The use of these shrubs should be restricted to sites with low fire hazard or low value.

Not all species within a recommended genus will prove equally effective in greenstripping. This argues for field testing of potential species and greater knowledge of plant species identification and ecology by the vegetation manager and right-of-way worker. There are trade-offs for both herb and shrub species in the ability to reduce tree invasion and the ability to reduce fire hazard. One of these two requirements may have to be relaxed for a given site, or combinations of species may need to be used. For example, a herbaceous species capable of reducing fire hazard may need to be planted with a highly flammable shrub species that is very resistant to tree invasion.

## CONCLUSIONS

Research suggests that greenstripping has potential as a vegetation management method along right-of-ways at high fire hazard or high value areas. A review of the literature suggests that greenstripping has the additional potential to reduce tree invasion and thus reduce intensity of hand cutting and herbicide application. Methods to create stable herbaceous and low shrub communities are being developed throughout North America. Greenstripping is a variant of these methods in that greenstripping also requires plants to reduce fire hazard.

Greenstripping can be the preferred management option in the absence of fire for financial, environmental and social reasons including public pressure to reduce herbicide use. Greenstripping may also improve aesthetics, control erosion and maintain biodiversity (through protection of disturbance-sensitive species). Greenstripping can be the preferred option if it can extend the treatment cycle, reduce treatment intensity and thereby reduce hand cutting costs or reduce herbicide use in sensitive natural areas or urban centers.

These conclusions are tentative because there are several gaps in knowledge about greenstripping and gaps in the application of this knowledge. The Greenstripping Project at Laurentian University is continuing its research program. Field experiments are planned to test the efficacy of greenstripping species to reduce ignition, fire spread, tree establishment and growth. In addition, the Greenstripping Project is proposing to investigate site preparation, establishment and maintenance methods, as well as horticultural (propagation) methods to increase the cover of greenstripping shrubs on the right-of-way. The Project proposes to estimate costs to permit comparison with other vegetation management methods. Greenstripping has the potential to reduce fire hazard and tree invasion. The effectiveness and cost of greenstripping need to be determined by scientific experiments.

## ACKNOWLEDGEMENTS

I thank Bell Canada, CP Railway and Ontario Ministry of Natural Resources for funding. I thank my colleagues from Laurentian University, Université du Sherbrooke, Ontario Ministry of Natural Resources, and Ontario Forest Research Institute for advice and logistical support. Chantal L. Sarrazin-Delay conducted the time-to-ignition experiments and regression analyses as part of her M.Sc. research. My thanks to field assistants for their help, and to the governments of Ontario and Canada for providing money for wages. I thank personnel from Canadian Forest Service, CN Rail, Department of National Defence (Canada), E.B. Eddy Forest Products Ltd., Ontario Hydro, Ontario Ministry of Transportation, Ontario Northlands Transportation Commission, TransCanada Pipelines, United States Department of Agriculture: Forest Service, University of Waterloo, Wisconsin Central Railway and Wisconsin Department of Natural Resources for their comments and advice. My thanks to family and friends for their support.

## REFERENCES

Abrahamson, L.P., C.A. Nowak, P.M. Charlton, and P.G. Snyder. 1992. Cost effectiveness of herbicide and non-herbicide vegetation management methods for electric utility rights-of-way in the northeast: state-of-the-art review and annotated bibliography. Final Report NMPC Project JC28477AGP. Niagara Mohawk Power Corporation, Syracuse, New York.

Allen, S.E., H.M. Grimshaw, and A.P. Rowland. 1986. Chemical analysis. In: Methods in Plant Ecology. P.D. Moore and S.B. Chapman, eds., 2nd edition. Blackwell Scientific Publications, Oxford, England. pp. 285–344.

Arnup, R.W., B.J. Dowsley, L.J. Buse, and F.W. Bell. 1995. Field guide to the autecology of selected crop trees and competitor species in northeastern Ontario. NEST Field Guide FG-005, Ontario Ministry of Natural Resources, Northeast Science and Technology, Toronto, Ontario.

(ASTM) American Society for Testing and Materials. 1993. Standard test method for gross calorific value of coal and coke by the adiabatic bomb calorimeter. In: ASTM Fire Test Standards. ASTM Committee E-5 on Fire Standards, ed., 4th edition. American Society for Testing and Materials, Philadelphia, Pennsylvania. pp. 271–278.

Balisky, A.C. and P.J. Burton. 1993. Distinction of soil thermal regimes under various experimental vegetation covers. Canadian Journal of Soil Science, 73: 411–420.

Bentley, C.V. and F. Pinto. 1994. The autecology of selected understory vegetation in central Ontario. Central Region Science and Technology – North Bay, CRST Technical Report no 31/ VMAP Technical Report no 93-08, Ontario Ministry of Natural Resources, North Bay, Ontario.

Berkowitz, A.R. and C.D. Canham. 1995. Ecological perspectives on tree invasion in rights-of-way: Net competitive effects of intact vegetation. In: Proceedings of the Fifth International Symposium of Environmental Concerns in Rights-of-way Management. D.J. Doucet, C. Séguin, and M. Giguère, eds. Hydro Québec, Montréal, Quebec. pp. 54–58.

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. Hutnik. 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. Hutnik, and S.A. Liscinsky. 1991. Prediction of cover type on rights-of-way after maintenance treatments. Journal of Arboriculture, 17: 238–243.

Brown, D. 1989. The use of cover crops for the maintenance of rights-of-way vegetation: a survey of the literature on succession, cover crops, competition and trees. Report no 89-275-K. Ontario Hydro Research Division, Toronto, Ontario.

Buse, L.J. and F.W. Bell. 1992. Critical silvics of selected crop and competitor species in northwestern Ontario. Northwestern Ontario Forest Technology Development Unit. Ontario Ministry of Natural Resources, Thunder Bay, Ontario.

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. In: Proceedings of the Fifth International Symposium of Environmental Concerns in Rights-of-way Management. D.J. Doucet, C. Séguin, and M. Giguère, eds., Hydro Québec, Montréal, Quebec. pp. 81–86.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud, and D. Williams. 1983. Fire in Forestry. Vol. I: Forest Fire Behavior and Effects. Vol. II: Forest Fire Management and Irganization. Krieger Publishing Company, Malabar, Florida. pp. 1–30, 207–230.

Consortium F.R.D.F — Sauger. 1992. Controle biologique de la vegetation incompatible avec les lignes de transport d'electricite d'Hydro-Québec. Phase II: Essais sur le terrain (1992). Rapport d'etape, vice-presidence environnement. Hydro Québec, Montréal, Quebec.

Dore, W.G. and J. McNeill. 1980. Grasses of Ontario. Monograph 26. Research Branch, Agriculture Canada, Hull, Quebec.

Dreyer, G.D. and W.A. Niering. 1986. Evaluation of two herbicide techniques on electric transmission rights-of-way: development of relatively stable shrublands. Environmental Management, 10: 113–118.

Fitch, R.K. and C.J. Wright. 1991. Rail transportation systems. In: Fire Protection Handbook. A.E. Cote, and J.L. Linville, eds., 17th edition. National Fire Protection Association, Quincy, Massachusetts. pp. 8-263 to 8-279 XVI.

Frankton, C. and G.A. Mulligan. 1987. Weeds of Canada. NC Press Ltd., Agriculture Canada and the Canadian Government Publishing Centre, Supply and Services Canada, Toronto, Ontario.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, 2nd edition. The New York Botanical Garden, Bronx, New York.

Glover, J.D. and D.H. Arner. 1995. The effect of glyphosate and prescribed burning on leguminous and woody plants on rights-of-way. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Right-of-Way Management. G.J. Doucet, C. Sequin, and M. Giguère, eds., Hydro Québec, Montréal, Quebec. pp. 92–94

Haeussler, S., D. Coates, and J. Mather. 1990. Autecology of common plants in British Columbia: A literature review. FRDA Report no. 158. Forestry Canada and British Columbia Ministry of Forests, Victoria, British Columbia.

Hall, I.V., L.P. Jackson, and C.F. Everett. 1973. The biology of Canadian weeds. 1. *Kalmia angustifolia* L. Canadian Journal of Plant Science, 53: 865–873.

Hardy BBT Limited. 1989. Manual of plant species suitability for reclamation in Alberta, 2nd edition. Reclamation Research Technical Advisory Committee, Report No. RRTAC 89-4. Alberta Land Conservation and Reclamation Council, Edmonton, Alberta.

Hill, J.D., C.D. Canham, and D.M. Wood. 1995. Patterns and causes of resistance to tree invasion in rights-of-way. Ecological Applications, 5(2): 459–470.

Hogenbirk, J.C. 1996a. Report of the Fire Hazard Reduction Project. Unpublished report prepared for the Ontario Ministry of Natural Resources. With one section co-authored with Chantal L. Sarrazin-Delay. Laurentian University, Sudbury, Ontario.

Hogenbirk, J.C. 1996b. The potential role of greenstripping in right-of-way vegetation management. Unpublished report prepared for Bell Canada and CP Rail System. With one section co-authored with Chantal L. Sarrazin-Delay. Laurentian University, Sudbury, Ontario.

Hogenbirk, J.C. and C.L. Sarrazin-Delay. 1995. Using fuel characteristics to estimate plant ignitability for fire hazard reduction. Water, Air, and Soil Pollution, 82(1/2): 161–170.

Hogg, E.H. and V.J. Lieffers. 1991. The impact of *Calamagrostis canadensis* on soil thermal regimes after logging in northern Alberta. Canadian Journal of Forest Research, 21: 387–394.

Horsley, S.B. 1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research, 7: 205–216.

Lautenschlager, R.A. 1995. Competition between forest brush and planted white spruce in north-central Maine. Northern Journal of Applied Forestry, 12(4): 163–167.

Loomis, R.M. and R.W. Blank. 1981. Summer moisture content of some northern Lower Michigan understory plants. Research Note, NC-263. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Loomis, R.M., P.J. Roussopoulos, and R.W. Blank. 1979. Summer moisture contents of understory vegetation in northeastern Minnesota. Research Paper NC-179. USDA Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Louter, J.H., M. Kershaw, and A.M. Gordon. 1993. The autecology of competing non-crop vegetation on old field sites in southern Ontario. Science and Technology transfer Unit (East), Southern Region. Ontario Ministry of Natural Resources, Brockville, Ontario.

Luken, J.O. 1990. Directing Ecological Succession. Chapman & Hall, New York. pp. 1–33, 77–81.

Mallik, A.U. 1993. Ecology of forest weed of Newfoundland: Vegetative regeneration strategy of *Kalmia angustifolia*. Canadian Journal of Botany, 71: 161–166.

Martell, D.L., S. Otukol, and B.J. Stocks. 1987. A logistic model for predicting daily people-caused forest fire occurrence in Ontario. Canadian Journal of Forest Research, 17: 394–401.

Meilleur, A., H. Véronneau, and A. Bouchard. 1992. Le controle biologique de la vegetation incompatible avec les lignes de transport d'electricite d'Hydro-Québec. Phase III: Travaux experimentaux sur les arbustaies. Rapport annuel, vice-presidence environnement, Hydro-Québec, par le groupe de recherche "Haut-Sainte-Laurent: ecologie et amenagement", Universite de Montréal. Hydro-Québec, Montréal, Quebec.

Meilleur, A., H. Véronneau, and A. Bouchard. 1994. Shrub communities as inhibitors of plant succession in southern Québec. Environmental Management, 18(6): 907–921.

Niering, W.A. and F.E. Egler. 1955. A shrub community of *Viburnum lentago*, stable for twenty-five years. Ecology, 36: 356–360.

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.

Niering, W.A., G.D. Dreyer, F.E. Egler, and J.P. Anderson Jr. 1986. Stability of a *Viburnum lentago* shrub community after 30 years. Bulletin of the Torrey Botanical Club, 113(1): 23–27.

Pellant, M. 1990. The cheatgrass-wildfire cycle — are there any solutions? In: Proceedings of the Symposium on Cheatgrass Invasion, Shrub Die-off and Other Aspects of Shrub Biology and Management. Las Vegas, Nevada, April 5–7, 1989. E.D. McArthur, E.M. Romney, S.D. Smith, P.T. Tueller, compilers. USDA Forest Service, Intermountain Research Station, Ogden, Utah. pp. 11–18.

Pellant, M. 1994. History and applications of the Intermountain greenstripping program. In: Proceedings — Ecology and Management of Annual Rangelands. 18–21 May 1992, Boise, Idaho. S.B. Monsen, S.G. Kitchen, compilers. USDA Forest Service, Intermountain Research Station, Ogden, Utah. pp. 63–68.

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(5): 956–965.

Polster, D.F. and L.-M. Landry. 1995. 1995 vegetation management, Algoma Division, CP Railway Internal Correspondence, File: ME005703-OM01221. 23 January 1995. Unpublished Report.

Robinson, S., S. Clare, and M. Leahy. 1992. Pasture production. Publication 19. Ontario Ministry of Agriculture and Food, Toronto, Ontario.

Ruel, J.-C. 1992. Impact de la competition exercee par le framboisier (*Rubus idaeus* L.) et les feuillus de lumiere sur la croissance du sapin (*Abies balsamea* (L.) Mill.) en regeneration. Canadian Journal of Forest Research, 22: 1408–1416.

Séguin, C. 1995. Hydro-Québec research program on biological control for rights-of-way vegetation management. In: Proceedings of the Fifth International Symposium of Environmental Concerns in Rights-of-way Management. D.J. Doucet, C. Séguin, and M. Giguère, eds. Hydro Québec, Montréal, Quebec. pp. 180–182.

Shribbs, J.M. and W.A. Skroch. 1986. Influence of 12 ground cover systems on young 'smoothee golden delicious' apple trees I. Growth. Journal of the American Society for Horticultural Science, 111(4): 525–528.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry. The Principles and Practice of Statistics in Biological Research, 3rd edition. W.H. Freeman and Company, New York. pp. 247–249.

Soper, J.H. and M.L. Heimburger. 1982. Shrubs of Ontario. Royal Ontario Museum, Toronto, Ontario.

Suffling, R. 1979. Environmental aspects of cover crops on Ontario Hydro rights-of-way. Waterloo Research Institute Project No. 707-11. University of Waterloo, Waterloo, Ontario.

Sylvester, T.W. and R.W. Wein. 1981. Fuel characteristics of arctic plant species and simulated plant community flammability by Rothermel's model. Canadian Journal of Botany, 59: 898–907.

Thomas, G.S. 1990. Plants for Ground Cover. Saga Press Inc, Timber Press Inc, Portland, Oregon.

Venus, J.C. and D.R. Causton. 1979. Plant growth analysis: a re-examination of the methods of calculation of relative growth and net assimilation rates without using fitted functions. Annals of Botany, 43: 633–638.

Werner, P.A. and A.L. Harbeck. 1982. The pattern of tree seedling establishment relative to staghorn sumac cover in Michigan oldfields. The American Midland Naturalist, 108: 124–132.

## *BIOGRAPHICAL SKETCH*

***John C. Hogenbirk***

*Principal Researcher, Greenstripping Project, Department of Biology, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6, Canada*

John C. Hogenbirk is a Research Associate in the Department of Biology at Laurentian University. John has been the Principal Researcher with the Greenstripping Project since its inception in September 1992. The project has been investigating the use of selected plant and shrub species to achieve vegetation management objectives along right-of-ways. John has a B.Sc. and M.Sc. in Ecology from the University of Guelph and is currently finishing his Ph.D. (University of Alberta) which he interrupted to take on duties with the Greenstripping Project. John's Ph.D. research was on the consequences of climate change on boreal vegetation; examining the effects of fire and drought on wet-meadows.

# A History of Utility Transmission Right-of-Way Management in New York State

**Lawrence W. Jackson**

A chronological history of electric industry developments and regulatory milestones leads into a comprehensive coverage of today's concept of integrated vegetation management. Relevant legislation is discussed along with environmental considerations related to the various maintenance techniques. Herbicide use has declined since systemwide plans were adopted in 1982 and the techniques have become progressively more selective. This select approach has resulted in a more diverse vegetation cover, following the second treatment, which has improved wildlife habitat, minimized erosion, improved scenic quality and improved reliability. Treatment costs per acre, except for mechanical, have declined since 1982. The immediate future poses some relief from reporting requirements but no major change in the current regulatory–utility relationship is envisioned.

*Keywords*: New York State, right-of-way management, regulations, related agencies and laws, management techniques, treatment costs, herbicide use

## RELEVANT INDUSTRIAL AND REGULATORY MILESTONES

Evolution of electric transmission right-of-way management in New York can be divided into three distinct periods (see below).

### Pre-regulation (before 1971)

The first transmission line on record was built in 1896 and extended 26 miles from Niagara Falls to Buffalo. Line construction proliferated after World War II, resulting in more structured maintenance (see Table 1).

During this period, lines and ROW were maintained by line crews working out of operations offices. Engineers supervised these crews, and no natural resource specialists were hired until 1961. Seven investor-owned utilities plus the New York Power Authority (NYPA) emerged with four companies, Niagara Mohawk Power Corporation (NMPC), New York State Electric and Gas Corporation (NYSEG), Orange and Rockland Utilities, Inc. (O&R) and Rochester Gas & Electric Corporation (RG&E) resulting from consolidation of smaller companies.

In 1971 the Office of Environmental Planning was created within the New York State Department of Public Service to administer Article VII rules (one stop shopping) for construction of electric and gas transmission lines.

### Transition (1971–1982)

The new Office of Environmental Planning found a variety of approaches to management among existing companies. The larger franchises, NYSEG and NMPC, were relying heavily on helicopter spraying to maintain ROW while smaller companies used hand cutting or ground foliar treatments and NYPA used the hydro axe extensively. Recognition that comprehensive planning for maintenance was needed culminated in: (1) a policy statement and order for utilities to provide notification to the Departments of Environmental Conservation (DEC) and Health (DOH) regarding herbicide use and develop an internal training program for applicators (Opinion and Order 80-15 issued April 1980) and (2) new rules, Part 84 of the Public Service Law, for administering herbicides aerially and requirements for preparing systemwide ROW management plans and reporting annually on last year's treatments and the coming year's scheduled treatments (Opinion and Order 80-40 issued December 1980). In the two years following the latter Order, all investor-owned utilities prepared and submitted systemwide plans for review and approval by the Commission.

**Table 1. Electric utility milestones in New York State**

| | Year and Activity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Utility | Current company formed | 1st trans. line built | Voltage/ length (miles) | 1st line dept. formed | 1st ROW maint. unit | 1st year of chemical use | 1st Prof. ROW manager | ROW under comprehensive plan | Entire ROW system brought under the plan |
| Central Hudson | 1920s | N.D.[1] | N.D. | 1924 | N.D. | 1950s | 1961 | 1979 | 1981 |
| Consolidated Edison | 1882 | 1932 | 138 kV 62 | 1956 | 1960 | 1960s | 1972 | 1975 | 1980 |
| Long Island Lighting Co. | 1910 | 1928 | 66 kV N.D. | N.D. | 1960 | 1962 | 1990 | 1981 | N.D. |
| New York Power Authority | 1930s | 1950s | 345 kV N.D. | late 1950s | N.D. | N.D. | 1978 | 1981 | 1986–87 |
| New York State Electric & Gas Corp.[2] | 1929 | circa 1920s | N.D. N.D. | 1929 | N.D. | late 1940s | 1970 | late 1970s | 1988 |
| Niagara Mohawk Power Corp.[2] | 1950 | 1896 | N.D. 26 | 1950 | 1950s | 1950 | 1962 | 1978 | 1985 |
| Orange & Rockland Utilities, Inc.[2] | 1958 | 1913 | 34.5 kV 8 | 1913 | 1950s | 1950 | 1968 | 1970 | N.D. |
| Rochester Gas & Electric Corp.[2] | 1904 | 1921 | 34.5 kV 25 | 1904 | 1921 | 1950 | 1982 | 1978 | 1982 |

[1] N.D. = No data.
[2] Predecessor companies date back to 1800s.

**Regulation (1983–present)**

Since 1983, all investor-owned companies have filed annual reports of the previous year's treatment results and current year treatment schedules. All company transmission ROW are now managed under an approved systemwide plan. Treatment cycles vary from 3 to 8 years within companies with at least two cyclical treatments having occurred under systemwide plans.

## PUBLIC SERVICE COMMISSION ROLE IN MANAGEMENT

The staff of the Public Service Commission (staff) became involved in reviewing management practices of electric utilities in the early 1970s when the Office of Environmental Planning was established. The impetus was the infamous "Northeast Blackout" of 9 November 1965. To cut costs and save money, utilities had deferred maintaining rights-of-way (ROW). In response to massive public outcry, a major emergency effort was undertaken to control vegetation. Staff investigated the cause of this outage and explored mechanisms to prevent a recurrence. In response, the utilities instituted a massive program to control all brush (woody vegetation) on their ROW. Documentation by staff through the mid-1970s revealed that electric utilities in general were underestimating the importance of ROW maintenance. When budget shortfalls occurred or upper management felt cost-cutting was necessary, maintenance was one of the first items reduced. Maintenance budgets increased only after major outages. The two main methods used to control ROW vegetation were brush-hogging or broadcast aerial spraying. The first resulted in a clear-cut with extensive tree regrowth and was becoming increasingly costly. The second method was very effective in controlling woody growth but opened up the ROW to woody plant reinvasion and frequently resulted in off-site damage to native plants and crops.

A three-pronged approach was established to counter these problems. First, all utilities were required to institute a procedure for notifying DEC and DOH regarding protection of sensitive areas (e.g., residential and recreational areas, crops, water bodies, and potable water supplies) from herbicide contamination. A second requirement was a training program for all herbicide applicators. Thirdly, the Commission set forth rules requiring each utility to: submit annually for review and approval all targeted aerial spray sites; provide a comprehensive long range systemwide ROW management plan for Commission approval; and report annually the previous year's treatment results along with plans for the current year (Opinion and Order 80-40). These required plans, with periodic updating and special provisions for the Adirondack Park, remain today. Staff annually reviews submitted plans to determine compliance with their stated objectives, conducts field reviews with company representatives and files an end of year report.

## ENVIRONMENTAL CONSIDERATIONS IN MANAGEMENT

While environmental mitigation is addressed during the siting and construction stage, environmental considerations continue throughout the life of each facility. Experience has shown, particularly in agricultural areas and wetlands, that employment of carefully selected and applied mitigation techniques reduce the extent and duration of impacts (Macks, Morrell, and Strub 1997). Ultimately, environmentally sensitive areas and specific resources must be addressed in the long-term management plan.

### Aesthetics

A conscientious effort to avoid major exposure of a proposed transmission line to large numbers of the viewing public is paramount (Howlett 1979). Landscaping may be a solution in highly exposed areas but requires budgeted maintenance, including thinning, pruning and topping. Plantings may require fertilizer or lime in attractive residential and roadside areas where poor soils lack necessary pH or nutrient levels (Gaffney, Dickerson, Myers, Hoyt, Moonen, and Smith 1991). Recent research has improved the efficacy of tree growth regulators (TGRs) (Orr, Leonard, and Lentz 1989), but a better approach is to discourage tall tree planting under conductors by landowners and municipalities.

### Wildlife and fish

Selective mechanical cutting has improved habitat for breeding birds (Bramble, Byrnes, and Schuler 1984) and young animals (Bramble and Byrnes 1979) but is more costly than herbicide techniques and must be done more frequently (discussed later). Furthermore, clear cutting can have catastrophic effects on local populations (deWaal Malefyt 1985). Thus, ROW management in New York includes judicious selection and use of herbicides to maximize cover and food for indigenous species.

Where endangered or threatened species are encountered special measures are incorporated to protect their habitat. Noise has been mitigated near bat caves (FERC Order 4796-NY for small hydro projects near Watertown 1986) and lupine encouraged for Karner Blue butterflies (Smallidge and Leopold 1992). Other examples are the retention of basking sites for rattlesnakes and turtles (Commission orders issued in Article VII cases 94-T-0316 on 5 July 1994 and 91-E-0529 on 23 May 1995). Crossing lanes have been designed and maintained (Wiley and Marion 1980) and desirable foods encouraged for deer (Bramble and Byrnes 1979). Moderate to high densities of cervids, lagamorphs and rodents (Canham, Berkowitz, McAninch, McDonnell, and Ostfeld 1994) help maintain desirable vegetation cover while improving aesthetics for ROW viewers. Vegetation at stream crossings has been retained through selective clearing to provide shade for aquatic life and stabilized banks have improved habitat for fish and amphibians (Wilzbach and Cummins 1986; Lees 1993). Stream crossing devices such as fords, culverts and rip-rap are maintained as needed to provide optimum quality habitat for aquatic organisms. Deferred maintenance can cause breakdown of these devices resulting in slowed stream flow, increased sunlight and warming of cold water streams and increased runoff and siltation. Gates and fences are regularly repaired to prevent vehicles and livestock from gaining access to streams, thus preserving sensitive reaches and riparian habitat.

### Rare and protected plants

In addition to federal law, New York State laws protect listed plants (Mitchell, Sheviak, and Dean 1980; Young 1996). Listed species are exploited locally for their economic importance (gensing) or their attractiveness (orchids and ferns). Research is underway to find means to protect and encourage lady-slippers (Petersen 1996) and blue lupine (Smallidge and Leopold 1992) growing on ROW.

### Landuse

Systemwide plans take into consideration existing landuses and practices of local landowners since most ROW are held in easements. ROW cut across a variety of uses, each requiring specific management approaches.

*Agriculture*

To insure reliability, electric structures, especially lines of 115 kV or larger, require maintained access to structures. Thus fill roads with water bars or culverts will exist in fields and need occasional maintenance as per management plan specification.

*Forested areas*

Utilities treat tall growing trees on a 3–8-year cycle to preclude tree caused interruptions. Each franchise is divided into districts and individual ROW are treated once during an established cycle. Cycle length depends on franchise size, onsite vegetation and site characteristics.

*Residential areas*

ROW in these areas are regularly scrutinized by the public and require constant vigilance. Stream and road crossing buffers must be regularly maintained to provide required conductor clearance and each landowner must be contacted when edge trees need trimming. Utility foresters attempt to synchronize trimming with ground treatment but rapid growth, storm damage and landowner concerns may dictate more frequent treatment. Long Island Lighting Company (LILCO) actually has two separate maintenance programs for ground floor and overhead work.

*Commercial and industrial areas*
Individual trees on these properties are frequently in inconspicuous places and difficult to spot but cannot be ignored. Thus, aerial surveys are used to supplement ground patrols in locating individual trees needing trimming or removal.

### Wetlands
Any use of protected wetlands, with the exceptions of limited grazing and logging and other farm activities, requires a permit from DEC or the Corps of Engineers. Herbicide use within established buffers is limited to aquatic labeled herbicides applied selectively to target species as per label instructions and in accord with the company's systemwide ROW management plan and Commission Orders.

### Waterbodies
Streams, rivers, lakes, and ponds are all considered sensitive resources. All approved systemwide ROW management plans require buffers of 9.1 m (30 feet) or more and any trees or limbs dropped in these water bodies must be manually removed to an upland site. Stream crossing devices are regularly maintained. Otherwise, maintenance is carried out in accord with conditions in the systemwide plan, and specific ordering conditions in pertinent Article VII cases which include recommendations from DEC for classified [c(t)] trout streams.

### Watersheds and reservoirs
Where herbicides are proposed on or near drinking water sources, the DEC and DOH or county health department must be notified in accord with state statutes and provisions in the systemwide plan. Buffer zone widths vary depending on site conditions and recommendations of the authorizing agency(s) and any felled limbs and tops must be removed from the water manually.

## IMPLICATIONS OF VEGETATION MANAGEMENT

Major advances have occurred in the field of vegetation management since 1950, particularly since 1978. ROW technology has evolved from strictly mechanical to highly selective chemical applications. Integrated pest management or IVM is now in vogue as environmental groups press non-chemical approaches.

### Mechanical
Prior to 1940 ROW clearing generally entailed a complete grubbing of all vegetation to facilitate access for construction and subsequent maintenance. Trees threatening lines were cut with axes or bucksaws. Erosion control was not a big concern. The 1940s featured the introduction of chainsaws and more selective clearing. Subsequently, brush-hogs, brillions, cutterbars and clippers were developed and introduced to ROW management. Each technique has its limitations and advantages depending on site conditions, vegetation present, accessibility and the perception of on-site sensitivity by the ROW manager. Increased acreage (Table 2), and labor and equipment costs now influence ROW managers to seek alternative maintenance methods. Handcutting now (1995) averages \$332 per acre vs. \$247 for high volume foliar and \$162 for low volume foliar (Table 3). Mechanical methods are all still used by New York utilities, but on a site-by-site basis and mostly where herbicides are prohibited by regulation or landowner agreement.

**Table 2. NYS Electric transmission right-of-way data 1996 (inclusive of 34.5 to 345 kV voltage lines)**

| Utility | Total ROW miles | Brush acres | Total acres |
|---|---|---|---|
| NMPC | 9,005 | 48,060 | 78,536 |
| NYSEG | 3,974 | 32,000 | 47,686 |
| O&R | 379 | 1,187 | 4,461 |
| CHGE | 535 | 4,000 | 6,399 |
| Con Ed | 118 | 2,027 | 2,723 |
| RG&E | 710 | 1,600 | 2,400 |
| LILCO | 1,083 | 2,269 | N.A. |
| NYPA | 1,040 | 17,270 | 28,700 |
| Totals | 16,844 | 108,413 | 170,905 |

N.A. = Figures not available.

### Chemical
Since 1950, herbicide techniques have been the major tool for controlling unwanted vegetation on New York ROW. After World War II ammonium sulfamate combined with 2,4-D was the first chemical mix used extensively on ROW. The high effectiveness of 2,4,5-T used in combination with 2,4-D during the Vietnam War prompted its increased use on ROW from 1950 to 1978. In 1978, EPA withdrew its registration of 2,4,5-T over concerns of environmental contamination by dioxin, a persistent ingredient of the chemical. Since 2-4-D was not effective by itself and ammonium sulfamate, developed and approved for use in water supplies, was only partially effective on certain species, a host of new products — picloram, triclopyr and glyphosate in particular — have become the dominant ROW herbicides today. Imazapyr, and metsulfuron methyl are being used in combination with the above and ammonium fosamine has become popular in highly visible areas where it can be applied late in the season to avoid highly visible leaf discoloration. Diuron and sulfometuron methyl are used extensively in substations for bare ground control.

**Table 3. Herbicide use and average cost of various electric ROW treatments in New York State (1982–1995)[1]**

| Year | Total acres treated[2] | Total gallons conc. herbicide used[3] | Gallons herbicide used/acre | Average treatment cost ($) acre | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Foliar | | Basal | Cut stump | Cut/no treat. | Brushhog |
| | | | | Low vol. | High vol. | | | | |
| 1982 | 10,054 | Inc. | — | — | 215 | 295 | 366 | 385 | 414 |
| 1983 | 12,320 | 8,911 | 0.72 | — | 179 | 278 | 267 | 282 | 180 |
| 1984 | 11,399 | 9,221 | 0.81 | — | 246 | 265 | 204 | 310 | 254 |
| 1985 | 12,825 | 11,506 | 0.90 | — | 230 | 272 | 346 | 290 | 246 |
| 1986 | 12,639 | 9,827 | 0.78 | — | 270 | 376 | 420 | 457 | 434 |
| 1987 | 13,626 | 10,041 | 0.74 | — | 334 | 325 | 398 | 320 | 489 |
| 1988 | 16,382 | 10,284 | 0.63 | — | 301 | 428 | 392 | 393 | 333 |
| 1989 | 13,276 | 11,238 | 0.85 | — | 288 | 336 | 503 | 547 | 428 |
| 1990 | 10,242 | 6,686 | 0.65 | — | 296 | 318 | 871 | 627 | 435 |
| 1991 | 14,532 | 10,125 | 0.69 | — | 309 | 334 | 488 | 585 | 409 |
| 1992 | 12,028 | 6,870 | 0.57 | — | 282 | 322 | 418 | 453 | 346 |
| 1993 | 16,277 | 9,102 | 0.56 | 252 | 355 | 160 | 416 | 468 | 418 |
| 1994 | 16,497 | 8,623 | 0.52 | 164 | 282 | 269 | 425 | 425 | 372 |
| 1995 | 16,498 | 8,176 | 0.49 | 162 | 247 | 562 | 441 | 332 | 400 |

[1] Summary of data from six upstate investor-owned electric utilities in New York State (Niagara Mohawk Power Corporation, New York State Electric & Gas Corporation, Central Hudson Electric & Gas Corporation, Rochester Gas & Electric Corporation, Orange and Rockland Utilities, Inc. and Consolidated Edison Company of New York.

[2] These totals include all acres treated by any material (chemical or mechanical) in each given year. Unfortunately, it was not possible to separate mechanical acres from chemical acres for all years.

[3] Total herbicide used is reported here in concentrate chemical as purchased from chemical companies without dilution. Foliar applications are generally applied in a 3% solution in water while basal and cut stump applications may be applied in various mixes with water or oil. A common ratio is 50:50.

ROW applications have progressed from mostly helicopter (1950s–1970s) within the two largest companies (NMPC and NYSEG); to ground foliar, basal and cut/stump (1980s and 1990s) and more recently (1993 to present) low volume foliar. Reduced densities of incompatible species have allowed two companies (Central Hudson and O&R) to employ backpack low volume foliar as their primary technique.

### Prescribed burning

NMPC conducted experimental burns in the 1970s but several limitations have precluded its use as a major ROW technique. Lack of selectivity and ineffective root kill are its main drawbacks. The Nature Conservancy has proposed this technique on selected ROW sites dominated by pitch pine and scrub oak in the Albany Pine Bush and Long Island. Future applications will be limited to fire vegetation types where a specific burn plan has been worked out and confinement is assured.

### Biological

Control of vegetation through biological means has been mainly experimental. Most publicized is the effort to control purple loosestrife (*Lythrum salicaria*) through introduction of predatory beetles from Europe (Malecki, Blossey, Hight, Schroeder, Kok, and Coulson 1993). Beetles have been released at pre-selected sites but further releases are dependent on current results. Biotic agents can only be introduced where a host plant(s) is undesirable and affected landowners and involved agencies agree on a control program. Allelopathy and competition from clonal and rhizomatous species are being explored and pose potential for the future.

### Passive or no treatment (cultural)

In New York about 37% of all transmission ROW are treeless (Table 2). Thus the cost of vegetation management is decreased about a third by other ROW uses. Without these uses, the total maintenance cost to franchised utilities would rise from $9,869,387 to about $13,500,000. That is a powerful incentive for utilities to encourage landowners to continue to manage ROW which cross their property. Interestingly, total current (1994) electric transmission ROW maintenance expenditures of about $10 million represent only 4% of all operations and maintenance costs (Table 4).

## EFFECTS OF MANAGEMENT ON VEGETATION

Species composition and plant density are the two measures of vegetation change on New York ROW. Selectively maintained ROW inherently provide greater plant diversity by bisecting homogeneous plant communities, opening the ground to increased sunlight and freeing up moisture by tree removal (Canham, Berkowitz, McAninch, McDonnell and Ostfeld 1994).

**Table 4. Annual expenditures in the transmission area for 1994[1]**

| Utility | Electric ROW maintenance ($) | Total O&M transmission expenses[2] | |
|---|---|---|---|
| | | Electric ($) | Gas ($) |
| NMPC | 3,500,000 | 47,026,000 | N.A. |
| RG&E | 250,000 | 19,777,000 | N.A. |
| Con Ed | 976,000 | 91,424,000 | N.A. |
| NYSEG | 2,275,000 | 34,778,000 | 634,000 |
| LILCO | 1,600,000 | 59,418,000 | 6,605,000 |
| O&R | 693,000 | 10,789,000 | 8,026,000 |
| NYPA | N.A. | N.A. | N.A. |
| CHG&E | 575,000 | 8,539,000 | 1,679,000 |
| Corning Gas | — | — | 297,000 |
| National Fuel Gas | — | — | 152,699,000 |
| Columbia Gas | — | — | N.A. |
| St. Lawrence Gas | — | — | N.A. |
| Totals | 9,869,000 | 271,751,000 | 169,940,000 |

[1] Figures rounded to the nearest thousand. Only rural area gas companies are listed.
[2] N.A. = Figures not provided.

### Species composition

Biodiversity is highly related to the management technique employed; e.g., repeated brush-hogging on western New York ROW by NMPC has produced solid stands of clonal *Viburnum* sp. and gray dogwood (*Cornus rugosa*) which is desirable management wise but provides little or no diversity. Aerial spraying has produced the same species homogeneity by eliminating trees which resulted in moss and fern cover on acidic moist sites; hay scented fern (*Denstadia punctilobula)* in heavier soils on drier sites and little bluestem (*Andropogon scoparious*) on silt-loam well drained sites. More recently, selective techniques such as basal, cut/stump and low volume foliar have targeted individual clumps or stems of trees, which allows other species to sprout or set seed. Over time, these niches create more diversity both in species composition and age class. The change is most dramatic in the second to third vegetation treatment cycle (Jackson 1997).

### Plant density

Closely related soil and moisture are the two most important density related factors. Organically rich alluvial bottom land soils with a constant water supply encourage germination and plant growth and rarely have less than 95% plant cover. Subsoils, sandy soils and highly acidic soils generally support much lower plant densities. Aspect is also important, thus cooler more moist north and west slopes and alluvial bottoms require more frequent treatment. Since entire ROW are scheduled in a given year, alternate year treatments are not an option but the poor soil, drier sites usually require less attention. Plants most likely to dominate are prolific seed producers (e.g., fire cherry (*Prunus pensylvanica*) and tartarian honeysuckle (*Lonicera tatarica*)), and those with root sprouting tendencies (e.g., quaking aspen (*Populus tremuloides*), hay scented fern and grey dogwood).

### Integrated pest management

Integrated pest management as a management concept has existed for years but ROW managers who deal with plants almost exclusively prefer the term integrated vegetation management (IVM). IVM on ROW entails keeping all options of management open for consideration but justifying them based on vegetation inventories, site conditions and existing landuse. The concept, introduced in a Commission policy statement (Opinion 80-15, 1980), continues to require rationale and conditions for implementing any new management technique.

### Economic justification

Cost benefit has always been a cornerstone of Commission policy and practice in rate setting. It applies equally to environmental considerations. The imposition of alternative vegetation management techniques on utilities must show cost savings or, at a minimum, no major cost increases.

The means for assessing cost/benefit are not sophisticated. However, all costs associated with a given technique, including equipment, labor, chemicals, travel and overhead, must be documented. With the exception of the NYPA, electric utilities employ contractors for vegetation maintenance. Their bids include the above items plus a profit margin (about 10% of the total job cost). New techniques or chemicals are used on a trial basis for one or two years and evaluated for cost benefit before being incorporated into the management plan.

## RESULTS OF MANAGEMENT EFFORTS TO DATE

Three major goals of IVM on New York ROW since 1980 have been to: (1) increase vegetation diversity while eliminating tall growing trees; (2) reduce herbicide use through selective applications; and (3) evolve a stable cost efficient maintenance program. Through staff and company cooperation, dramatic success has been achieved for all three objectives. The evolution of vegetation change from undesirable to desirable vegetation has been documented (Jackson 1997). Current low volume foliar treatments can save 40–60% of the cost of high volume, 60–70% savings versus cut/stump treatment and 25–40% savings on basal bark treatments with the same or better control of unwanted trees (Table 3). While it may appear that costs have increased over the years (Table 3), an adjustment for inflation since 1983 (Table 5) shows an increase for mechanical treatment only (10%) while all other treatments declined from 13% (cut/stump) to 47% (basal bark). Furthermore, mechanical techniques require follow-up chemical treatment to achieve the required control (90–100% kill) of undesirable species.

**Table 5. Cost comparisons of various right-of-way treatments accounting for inflation, over 12 years of management[1]**

| Treatment technique | 1983[2] actual | 1994[3] actual | 1994[4] | % actual | Change adjusted |
|---|---|---|---|---|---|
| High volume foliar | 179 | 282 | 154 | +37 | –14 |
| Basal bark | 278 | 269 | 146 | –3 | –47 |
| Cut/stump treat | 267 | 425 | 231 | +37 | –13 |
| Cut/no-treat | 282 | 424 | 231 | +33 | –18 |
| Mechanical clearing | 183 | 373 | 203 | +51 | +10 |
| Average of all treatments | 238 | 355 | 193 | +33 | –19 |

[1] Trimming is not included since it was not consistently reported and is based on different units of measure.
[2] 1983 was the first year all investor-owned electric utilities reported complete data for management activities.
[3] 1994 is the most recent year with complete data.
[4] Adjusted 45.56% for inflation.

## THE FUTURE

Several trends are evident in the electric industry. Companies are currently being reorganized and downsized to make them more efficient, meaning more must be done with less. That requires excellent planning, tight budget control, better unit coordination and more use of electronic systems to collect, store and analyze data. This trend is likely to continue into the next century.

Deregulation of New York industry will continue but transmission and distribution (T&D) have not been a prime target to date. Both industry and the Commission currently see little advantage to deregulation of T&D activities. Thus the future relationship between regulators (Commission) and regulatees (T&D companies) will likely remain static. Easing of regulations is in order and underway which should result in a less adversarial atmosphere between the aforementioned parties.

New chemicals and delivery devices for herbicides will evolve though at a slower pace then the last 20 years due to increasing costs, registration requirements, and less government grant money. Biological research will continue to provide answers for individual troublesome species but the solutions will have limited adaptability to ROW and will require cooperation with other agencies and more involvement of affected landowners.

Public relations will become increasingly important and utilities will consider citizen advisory boards to coordinate public concerns on management and other issues. Cooperative management contracts with landowners or advisory groups on management issues are likely to increase as a consequence.

## ACKNOWLEDGEMENTS

The author thanks the seven investor-owned utilities and the New York Power Authority for providing history and data on their companies. Special appreciation is also due to my secretary, Cathy Watrobski, for her diligence in typing the text and tables and to John Smolinsky for editing the final draft.

## REFERENCES

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., W.R. Byrnes, and M.D. Schuler. 1984. The bird population of a transmission right-of-way maintained by herbicides. Journal of Arboriculture, 10(1): 13–20.

Canham, C.D., A.R. Berkowitz, J.B. McAninch, M.J. McDonnell, and R.S. Ostfeld. 1994. Vegetation dynamics along utility rights-of-way; factors affecting the ability of shrub and herbaceous communities to resist invasion by trees. Final technique report by Institute of Ecosystem Studies to Central Hudson Gas & Electric Corp., Millbrook, New York, pp. 297–339.

de Waal Malefyt, J.J. 1985. Effects of vegetation management on breeding bird populations along electric transmission rights-of-way. New York Fish and Game Journal, 32(2): 197–209.

Gaffney, F.B., J.A. Dickerson, R.E. Myers, D.K. Hoyt, H.F. Moonen, and R.E. Smith. 1991. A guide: Construction plantings on critical erosion areas. Syracuse, New York, pp. 1–36.

Howlett, B.E. 1979. Selecting designs, materials and colors for transmission structures in different environments. In: Proceedings of the Second Symposium on Environmental Concerns in Rights-of-Way Management. Ann Arbor, Michigan, 16–18 October. pp. 17-1; 17-9.

Jackson, L.W. 1997. Vegetation dynamics on a managed New York right-of-way (1977–1996). In: 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. Elsevier Science, Oxford, England.

Lees, A. 1993. Aquatic habitat enhancement and fish utilization of reclaimed pipeline stream crossings in Alberta. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 305–307.

Macks, D.D., D. Morrell, and J. Strub. 1997. Common environmental problems encountered during construction of major gas transmission lines. In: 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. Elsevier Science, Oxford, England.

Malecki, R.A., B. Blossey, S.D. Hight, D. Schroeder, L.T. Kok, and J.R. Coulson. 1993. Biological control of purple loose strife. Bioscience, 43(10): 680–686.

Mitchell, R.S., C.J. Scheviak, and J.K. Dean. 1980. Rare and endangered vascular plant species in New York State. Report of the State Botanist Office, Albany, New York, pp. 1–38.

Orr, J.W., S. Leonard, and J. Lontz. 1989. The use of tree growth regulators for utility line clearance. Arbor Age, January. pp. 18–23.

Peterson, A. 1996. The effect of electric transmission ROW clearing on a forest population of yellow lady slipper orchids in Clinton County, NY (unpublished report). New York State Electric and Gas Corporation, Binghamton, New York. pp. 1–17.

Smallidge, P.J. and D.J. Leopold. 1992. Evaluation of karner blue (Lycaeides melissa samuelis nabokov) habitat beneath transmission line rights-of-way in eastern New York. Final report to Niagara Mohawk Power Corporation, Syracuse, New York. December. pp. 1–187.

Wiley, C.H. and L.F. Marion. 1980. Transmission line corridor crossings for white tailed deer. Transactions Northeast Wildlife Conference, 37: 90–103.

Wilzbach, M.A. and K.W. Cummins. 1986. Influence of habitat manipulations on interactions between cutthroat trout and invertebrate drift. Ecology, 67(4): 898–911.

Young, S.M. 1996. New York Natural Heritage Program's rare plant status list. Report of New York Natural Heritage Program. Latham, New York. pp. 1–74.

## *BIOGRAPHICAL SKETCH*

***Lawrence W. Jackson***

*New York State Department of Public Service, Three Empire State Plaza, Albany, NY 12223-1350, USA*

Lawrence Jackson is currently employed as an Associate Aquatic and Terrestrial Ecologist with the New York State Department of Public Service in Albany, New York. His primary fields of interest are right-of-way management and wildlife management, particularly white-tailed deer. He has published nearly 50 articles on those two subjects in various journals and as separate unpublished reports over the last 30 years. His BS was obtained in Wildlife Management from the University of Maine and he studied toward an MS in Wildlife Management at Utah State University. Lawrence Jackson has also taken post-graduate courses at Keene State College and the State University of New York at Albany. He is a member of the Weed Science Society, The Ecological Society of America and The Wildlife Society where he currently serves as treasurer in the New York Chapter.

# Vegetation Dynamics on a Managed New York Right-of-Way (1977–1996)

**Lawrence W. Jackson**

Vegetation surveys were conducted on an upgraded electric transmission right-of-way in eastern New York with an initial ocular estimate of ground cover at the time of clearing (1977) and subsequent ocular surveys of 12 representative sites in 1983, 1991 and 1996. Objectives were to document treatment effectiveness and vegetation change over time. Plants were classified as mosses, ferns, grasses and sedges, forbs, shrubs, desirable trees and undesirable trees. Treatments of vegetation occurred in 1978 (basal with 2, 4, 5-T), 1983 (cut/stump with picloram), 1991 (cut/stump, foliar with glyphosate and imazapyr) and 1996 (spot foliar with glyphosate). Over the study period ground cover of mosses, ferns and grasses/sedges declined while forbs, shrubs and desirable trees increased. Undesirable trees were reduced to 5% or less ground cover on 10 sites with only one site increasing and one remaining stable. The basal treatment in 1978 eliminated many non-root sprouting species, but it took a follow-up cut/stump application in 1983 to remove root sprouting species. Subsequent treatments reduced undesirable species to 5% or less ground cover by 1996 on all but one site. Thus, major conversion to forbs, shrubs, and desirable tree species began in the second treatment cycle. Species numbers increased over the years in all but the moss group, with a regression analysis of variance yielding an f value of 438.97, df 1 (highly significant at the 0.05 level). While undesirable trees are now 5% or less of ground cover they continue to invade and will require continuous cyclical maintenance to preclude their escape into the wire security zone.

*Key words*: Vegetation dynamics, vegetation survey, ocular estimate, selective treatments, ground cover, conversion, biodiversity

## BACKGROUND

During the early 1970s, the New York Power Pool, which coordinates electrical usage and distribution for New York State electric utilities, identified a need for a stronger tie between the New York and New England electric power pools. A decision was made to upgrade an existing 115 kV line, constructed in 1939, to 345 kV to provide that link. The selected line was Reynolds Road-Alps located in Rensselaer County, New York, and extending from a substation near Troy some 17.9 km to the Alps substation near the Massachusetts border (Fig. 1).

A major power outage in 1965 blacked out much of the Northeast and raised concern about the adequacy of electric line maintenance statewide. The New York State Public Service Commission (PSC) certified this line in 1974 (Article VII, Case 26423) and construction took place in 1976 and 1977. Staff of the Department of Public Service (staff) selected this right-of-way (ROW) as representative of land uses encountered in the state for a study of vegetation trends through several treatment cycles. In order to establish a baseline for determining treatment types and intervals an inventory was needed. The subsequent inventory (Jackson and Pintal 1978) was used as a basis for developing a model plan for managing electric system natural resource components (Jackson 1978). In 1980, the PSC required all franchised electric utilities to submit a systemwide ROW management plan for their transmission system.

## OBJECTIVE

The basic objective of this study was to document and analyze the vegetation response 5, 13 and 18 years after clearing of the line and more specifically to evaluate the

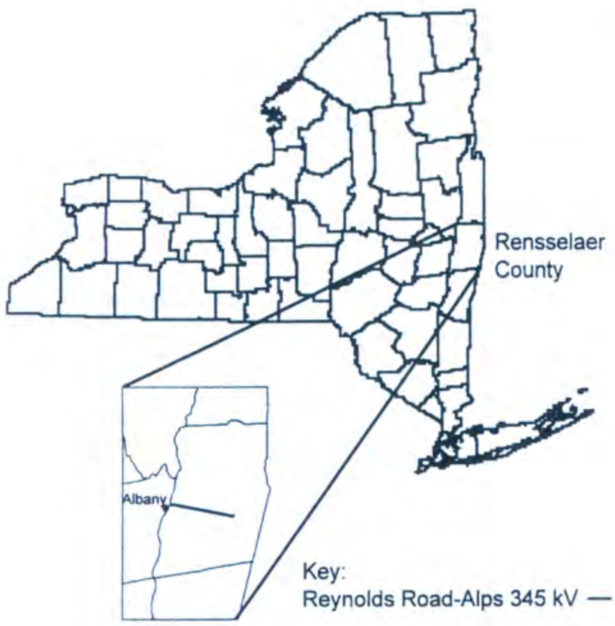



Fig. 1. Location of study area.

effectiveness of chemical follow-up treatments on undesirable tree species.

## METHODS AND ANALYSIS

In the summer of 1977, a baseline vegetation survey was conducted of the ROW, which included the original 1939 line and the newly cleared 345 kV portion. No attempt was made to inventory old and new ROW independently since the ROW would be treated in its entirety during each treatment cycle. The original ROW was handcut in the 1940s. Helicopter and ground foliar treatments were employed in the 1950s and 1960s. Surfaces of all fresh cut stumps on the new ROW were chemically treated during clearing. Follow-up basal bark treatment with 2, 4, 5-T took place in 1978; some spot cut/stump treatment (stems cut with chain saw and stumps sprayed using a squeeze bottle with picloram) was employed on the west end of the line in 1983. A combined cut/stump and foliar treatment occurred in 1991 using glyphosate and imazapyr and some spot ground foliar (with glyphosate) took place in 1996. The vegetation survey, conducted by an initial observer, was an ocular estimate of percent cover of existing species on the ROW. The observer zigzagged as he walked the ROW and kept a written tally of species encountered. Whenever there was an obvious cover type change, the observer stopped and estimated the percent cover of each species at that site. Species were grouped into seven phylogenetic categories: mosses, ferns, grasses/sedges, forbs, shrubs, desirable trees and undesirable trees. The distinction between desirable and undesirable was average height at maturity (7.2 m in this case). A second observer spot-checked the tallies to verify their accuracy. Established plots with known densities were used as a reference and periodic check by the observer. The 17.9 km ROW was divided into 53 sites during the initial survey. In the summer of 1983, 12 of these sites were re-evaluated by the author. Nine of the sites were representative of the 25 northern hardwood sites found on this ROW where undesirable species had originally equalled or exceeded 10% of the plant cover. The other three sites were included because of their unique composition of vegetation. The same 12 sites were again evaluated by the author in June of 1991 and 1996 using the ocular techniques employed previously.

The Friedman Test (Conover 1980) was used to discern if differences occurred between sites and years within the seven different plant groups. The hypothesis was that in a random table of percent cover for each plant group values have the opportunity to be equal but some may differ.

A contingency table (Conover 1980) was used to determine whether or not values of T were significant or not at the 0.05 level.

To determine if differences occurred between plant number and years of species a regression analysis of variance was employed (Steele and Torrie 1960). Calculations were made with an SAS program (1997). Again, for the hypothesis there is equal opportunity for numbers to be the same over the years in each plant group. It should be noted, however, that site observed changes over time and climatic features undoubtedly affected species numbers within plant groups on individual sites.

## RESULTS

The percent cover by plant group of the 12 sites selected for re-survey in 1983, 1991 and 1996 was summarized and tabulated (Table 1). Estimated plant cover for those years is compared with 1977. Table 2 is a summary of vegetation cover trends for each major phylogenetic plant group.

### Mosses and Ferns

As might be expected following conversion of closed canopy to open conditions where sunlight is dramatically increased and desiccation is more rapid, both mosses and ferns declined. Haircap (*Polytrichum commune*) was by far the most common moss in 1977, with sphagnum (*Sphagnum* sp.) common on wet areas within sites. By 1983, however, with more desirable woody vegetation providing more shade and moisture, increases were recorded at four sites. These gains reversed in 1991 and 1996 with mosses declining on eight sites in 1991 and five sites in 1996. Hayscented (*Dennstaedtia punctilobula*) and bracken fern (*Pteridium aquilinum*) were most common on upland sites with sensitive (*Onoclea sensibilis*) and interrupted fern (*Osmunda interrupta*) be-

**Table 1. Total plant density and average density in percent ground cover by plant group and year surveyed**

| Plant group | 1977 | | 1983 | | 1991 | | 1996 | |
|---|---|---|---|---|---|---|---|---|
| | Total | Avg. | Total | Avg. | Total | Avg. | Total | Avg. |
| Mosses | 57 | 4.75 | 58 | 4.83 | 43 | 3.58 | 49 | 4.08 |
| Ferns | 85 | 7.08 | 54 | 4.50 | 60 | 5.00 | 75 | 6.25 |
| Grasses | 237 | 19.75 | 291 | 24.25 | 187 | 15.58 | 209 | 17.42 |
| Forbs | 320 | 26.67 | 290 | 24.17 | 255 | 21.25 | 375 | 31.25 |
| Shrubs | 270 | 22.50 | 191 | 15.92 | 373 | 31.08 | 323 | 26.92 |
| Desirable trees | 97 | 8.08 | 98 | 8.17 | 185 | 15.42 | 131 | 10.92 |
| Undesirable trees | 133 | 11.08 | 218 | 18.17 | 101 | 8.42 | 49 | 4.08 |

**Table 2. Plant composition change by site from 1977 for each survey period**

| Plant group | Increase | | | Decrease | | | No change | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1983 | 1991 | 1996 | 1983 | 1991 | 1996 | 1983 | 1991 | 1996 |
| Mosses | 4 | 1 | 2 | 6 | 8 | 5 | 2 | 3 | 5 |
| Ferns | 2 | 2 | 3 | 6 | 9 | 7 | 4 | 1 | 2 |
| Grasses | 6 | 2 | 4 | 5 | 8 | 8 | 1 | 2 | 0 |
| Forbs | 4 | 3 | 6 | 7 | 6 | 4 | 1 | 3 | 2 |
| Shrubs | 0 | 11 | 7 | 12 | 1 | 3 | 0 | 0 | 2 |
| Desirable trees | 5 | 7 | 7 | 5 | 3 | 3 | 2 | 2 | 2 |
| Undesirable trees | 5 | 1 | 1 | 3 | 9 | 10 | 4 | 2 | 1 |

ing common in wet areas. All ferns on only two sites (2 and 53) increased between 1977 and 1991. The $T_2$ test revealed ($T_2 = 2.68$) that significant differences do exist between mosses within sites and between years at the 0.05 level and likewise differences occur for the ferns ($T_2 = 3.16$).

### Grasses including Sedges

Grasses increased on only four sites (2, 11, 39 and 44) while decreasing on eight sites over the study period. A reciprocal relationship occurred for forbs which increased on six sites, while declining on only four sites. On three sites where grasses declined, forbs decreased as well, but on three other sites forbs increased where grasses declined. However, on the three sites where undesirable trees increased dramatically in 1983 (sites 11, 47 and 53), grasses and forbs decreased correspondingly. Yet, when trees were dramatically reduced (1991) grasses and forbs expanded (site 11), stayed the same (site 47) or stayed the same for grass while forbs increased (site 53). On the latter two sites, shrub increases made up the difference. Three grasses (*Poa canadenis, Koelaria cristata, Phleum pratense*) were common to all sites though not predominant, with 5% or less cover for each species. Poverty grass (*Danthonia spicata*) and little bluestem (*Andropogon scoparius*) were predominant [45 and 54% on two sites (24 and 34)] in 1983 but declined thereafter, while sedge (*Carex* sp.) was common to most sites but exceeded 5% on only two sites (1 and 8 in 1983). The $T_2$ test ($T_2 = 2.52$) revealed that significant differences occur between the cover of grasses among sites and over the years.

### Forbs

Forbs varied widely in density and composition, with the goldenrods (*Solidago* sp.), collectively, being most important. They (*S. canadensis, S. rugosa, S. altisima, S. gigantea, S. graminifolia, S. squarosa*) comprised about 5–8% of the cover on all sites but site 2 where they increased from 8 to 15% in 1983 and then declined to 4% by 1991. The $T_2$ test for forbs revealed that ($T_2 = 2.37$) significant differences occur between sites and years for this plant group.

### Shrubs

Shrubs declined on all 12 sites from 1977 to 1983 (Table 1). Decreases were most dramatic on sites 11 and 34. On site 11, undesirable trees (primarily black locust (*Robinia pseudoacacia*)) became the major plant group whereas on site 34, grasses were most common. On five other sites, (2, 24, 39, 44 and 47), the decrease was 5% or more. Shrubs increased on 11 of these sites in 1991 but by 1996 shrubs had declined slightly on eight of the sites to the advantage of forbs. Shrub gains were at the expense of all other plant groups, but varied from site to site. Some 42 shrub species were encountered.

Currants (*Ribes* sp.), holly (*Ilex* sp.) and roses (*Rosa* sp.) were lumped by genera. Briars were included as shrubs since they have semi-woody stems, but were tallied by species. Cumulatively, briars were the major shrub component with blackberry (*Rubus allegheniensis*), raspberry (*Rubus idaeus*) and dewberry (*Rubus hispidus*) present on nearly every site. Gray dogwood (*Cornus racemosa*) was the most important individual shrub, comprising up to 11% of the plant cover (site 29). Arrowwood (*Viburnum dentatum*) was also present on most sites, although not quite as ubiquitous as gray dogwood, and ranged up to 10 and 12% of plant cover (sites 44 and 23, respectively). Other important species were roses, grape (*Vitis* sp.), virgin's bower (*Clematis virginiana*) and bush honeysuckle (*Diervilla lonicera*). The $T_2$ test revealed ($T_2 = 4.24$) that significant differences occur between sites and years for this plant group.

### Desirable Trees

Seventeen species of desirable trees were identified. Blue beech (*Carpinus caroliniana*), fire cherry (*Prunus pensylvanica*) and hop hornbeam (*Ostrya virginiana*) are included, although these species were also considered undesirable wherever maximum height growth exceeded the limits of the wire security zone. In 1983, staghorn sumac (*Rhus typhina*) was found on all but site 23 and comprised up to 15% of plant cover on those sites; fire cherry and hawthorn (*Crataegus* sp.) were also common to most sites, although never comprising more than 3% of the cover even collectively. In addition to the five species already discussed, notable increases in density occurred over the study for both smooth sumac (*Rhus glabra*) and juneberry (*Amelanchier* sp.). The $T_2$ test revealed ($T_2 = 2.93$) significant differences between sites and years within this plant group.

### Undesirable Trees

From 1977 to 1996 undesirable tree species decreased on 10 sites and increased on only one, so by 1996 aggregate densities of these species were 6% or less on all but site 34. Between 1983 and 1996, undesirables went from 5 to 20% on site 34 with gray birch (*Betula populifolia*) and red maple (*Acer rubrum*) increasing 10 and 3%, respectively, and aspen (*Populus tremuloides*) remaining stable. On site 11, black locust was not effectively controlled and increased from 2 to 50% and comprised 5/6 of the undesirable vegetation on that site in 1983. Subsequent treatment reduced it to 1% in 1991, but by 1996, it was back to 4%.

Interestingly, the same undesirable species occurred in roughly the same proportion (1–5%) on all sites regardless of composition trend. Those species were red maple, white ash (*Fraxinus americanus*), gray birch and quaking aspen. The notable exceptions to this principle were white pine and hemlock (site 53) and black locust (site 11). While densities of the 25 identified species vary somewhat, red maple, white ash, red oak, gray birch and quaking aspen occur most frequently. Black locust is also a problem on select sites. The $T_2$ test revealed ($T_2 = 9.95$) highly significant differences between sites and years in this group.

### Herbicide Effectiveness

The uniqueness of site 11, because of black locust, has been discussed previously. While the basal application in 1983 was ineffectual, a site specific cut/stump treatment reduced that species to 1% by 1991. The shrub component declined on all sites from 1977 to 1983 undoubtedly due to translocation of chemical and overspray but responded to treatments and exceeded 1977 levels on seven sites by 1996. The same rationale applies to desirable (notably sumac) trees and forbs which declined on several sites from 1977 to 1983 but rebounded and exceeded 1977 levels on seven and six sites, respectively, by 1996. The three remaining groups: mosses, ferns and grasses all declined on six, seven and eight sites, respectively, over the study. Their decline is attributed to interspecific competition and site factors. They were not targeted but chemicals indirectly affected displacement by providing interstices for new plant invasion.

### Species Composition and Biodiversity

Forbs, shrubs and desirable trees increased by 5, 5 and 3% respectively, over the study while mosses, ferns, grasses, and undesirable trees declined on average by 1, 1, 2 and 7%. In 1996, shrubs were the dominant group on six sites, forbs on four sites, and desirable trees and ferns on one site each. On no site did the average density of any group exceed 32% (Table 1). The mosses, while declining overall, are down by only 1% and remain on nine sites; being eliminated only on sites 11, 23 and 47. Ferns declined slightly as well but have disappeared only at sites 11 and 24 and appeared at site 1 in 1996 where none existed before. The one site where ferns have increased dramatically is site 53 where five species, lead by hayscented, now comprise 36% of the ground cover.

A compilation of species by plant groups and year was made to assess any change in numbers (Table 3). With the exception of the mosses and undesirable trees,

**Table 3. Species diversity index**

| Plant group | Number of species by year | | | |
|---|---|---|---|---|
| | 1977 | 1983 | 1991 | 1996 |
| Mosses | 4 | 3 | 3 | 4 |
| Ferns | 5 | 6 | 7 | 10 |
| Grasses | 12 | 16 | 20 | 17 |
| Forbs | 54 | 53 | 67 | 76 |
| Shrubs | 25 | 29 | 31 | 37 |
| Desirable trees | 11 | 13 | 15 | 18 |
| Undesirable trees | 15 | 21 | 18 | 16 |
| Totals | 126 | 141 | 161 | 178 |

species numbers increased in all other groups over the years. The magnitude of increase was confirmed through a regression analysis of variance which yielded an f value of 438.97 (df 1; 0.05 level) and revealed that highly significant differences exist between plant groups and years. The probability of f being non-significant was only 0.0023 (SAS 1997). Interestingly, while species numbers declined slightly (by five) for undesirable trees from 1983 to 1996, 16 species still remain after nearly 20 years of maintenance though at a much reduced density.

## DISCUSSION

It would be unsound to draw definitive conclusions based on a direct comparison of plant group types by percent cover since several cover comparisons were within a 5% range, and ocular estimates may be biased by as much as 5%. Furthermore, differences exist between sites with regard to slope, aspect, soil and moisture regime and for these reasons only tests for overall differences were conducted. Some general conclusions are valid, however.

Traditional theory of succession envisioned a progression from lower to higher plant groups. Egler (1954) challenged this theory and instead introduced the concept of initial floristic relay. Subsequent studies (Bramble, Burns, and Hutnik 1990; Bramble, Burns, Hutnik, and Liscinsky 1996) generally supported Egler's theory and revealed that certain plants (e.g., goldenrods, hayscented ferns and poverty grass) discourage woody plant invasion and maintain stable communities for several years.

This study confirmed those earlier findings with clonal species maintaining their numbers or increasing over time. A downward trend is natural for most mosses, ferns and grasses on a newly-cleared ROW treated with selected herbicide applications. In fact, mosses, ferns and grasses increased on only two, three and four sites, respectively, through 1991. Certain species of these groups, particularly haircap moss and hayscented fern, might be expected to increase where herbicides are broadcast, but this was not the case here except on site 53 where, hayscented fern probably benefitted from earlier helicopter applications.

On only three sites (11, 23 and 47) did a progression from lower to higher plant groups occur with undesirable trees increasing dramatically from 1977 to 1983. Subsequent treatments, however, reduced undesirables to 5% or less on all these sites by 1996. Shrubs had become the dominant group (50% plus) on sites 23 and 47 by 1991 but shrubs declined on both sites by 1996 to the benefit of forbs and desirable trees. Sites 8 and 11 continue to be in transition with slight declines in the shrub and desirable tree species and grasses and forbs still dominating. Staghorn sumac and gray dogwood are increasing on both sites, however, and under selective management should eventually dominate.

Disturbance is the only logical explanation for forb abundance: 20–40% on nine sites in 1983. By 1991 forbs were still in transition, increasing on five sites and declining on six others. The lack of increase in shrubs and desirable trees on certain sites allows continued space for forbs. Little bluestem and some goldenrods (*S. rugosa*, *S. graminifolia*, *S. altisima*) are quite herbicide-resistant and tend to increase where broadcast herbicide application is practised (Bramble, Burns, Hutnik, and Liscinsky 1996). These species undoubtedly flourished on the old existing ROW prior to clearing for the Article VII line in 1977, and have extended their presence through underground rhizomes into the new ROW.

The reason(s) for shrubs and desirable trees not increasing on certain sites are site-specific and include, beyond edaphic features, a probable combination of recreational use (trail bikes and horseback riding), erosion, land use activities, herbicide use and biotic activity, particularly herbivory. The first two activities are confined almost exclusively to the access road (10–15% of the ROW). Erosion has been largely controlled by seeding, mulching and installation of diversion ditches in the first year after construction. This leaves land use, herbicide application and herbivory as the most likely factors influencing tree and shrub growth or lack thereof. Prior to 1983, herbicides were marginally effective (greater than 1% reduction of undesirable plant cover on only three sites). On four sites, the reduction was less than 1%, and on five sites, undesirable cover increased. The increase on three of these sites was dramatic (18–55% increase). Even on sites where undesirable species decreased, however, a residual undesirable cover of 5% or more remained in 1983.

Why did shrubs and desirable trees not increase more dramatically prior to 1983 since they were being released through clearing and selective herbicide applications? Ineffective herbicide control on root sprouting species, particularly aspen and black locust, probably explains the resurgence of these species on site 11 in 1983 and site 34 in 1996. At site 11, where sumac decreased from 15 to 1% and black locust increased simultaneously from 2 to 50%, it appears the sumac, which is highly susceptible to translocating chemicals and 2,4,5-T, was killed, while the black locust survived and increased by root suckering. A dramatic turn-around of shrubs occurred after 1983 from a decline on 11 sites to an increase on 11 sites. Species such as gray dogwood, arrowwood, dewberry, grape and poison ivy (*Rhus radicans*), which regenerate through above or underground rhizomes, have increased wherever they occur. Species such as common elder (*Sambucus canadensis*), hardhack (*Spirea tomentosa*), sweet fern (*Comptonia peregrina*), the blueberries (*Vaccinium* sp.), honeysuckles (*Lonicera* sp.), autumn olive (*Eleagnus umbellata*), choke cherry (*Prunus virginiana*) and beaked hazelnut (*Corylus americana*) which spread through seed dispersal, on the other hand, have remained stable or increased only slightly. Shade-tolerant species such as witchhazel (*Hamamelis* *virginiana*) and spice bush (*Lindera benzoin*) have not done well in full sunlight and are declining. The briars, other than dewberry, have generally declined on all sites as well which explains the shrub component decline on several sites in 1996. There are probably several reasons for this. The sandier sites to the west of the ROW have never favored briars. They are also very susceptible to herbicides and are killed by either direct contact foliar applications or by root absorption from basal or cut/stump applications. As woody shrubs and desirable trees continue to spread, briars will probably continue to decline. Interestingly, dewberry has continued to spread as edaphic features, soil and moisture, favor it. Also, because of its decumbent growth form, it avoids contact with foliar sprays. Sumac, in the desirable tree group, is undoubtedly similar in response to the rhizome spreading shrubs. It is very susceptible to foliar sprays and root pickup of chemicals such as 2,4,5-T and picloram because of its upright growth form, physiology and spreading root system. Given the opportunity, however, it spreads rapidly as evidenced by documentation at sites 1, 2, 11, 24, 29 and 39 in 1991. Surprising and unexplained, is its decline on all those sites except 24 in 1996.

Other studies (Canfield, Berkowitz, McAninch, McDonnell, and Ostfeld 1994; Adams and Geis 1981) have shown herbivory, particularly by small rodents (*Microtus* and *Peromyscus* sp.), deer (*Odocoileus virginiana*) and rabbits (*Sylvilagus* sp.) to play a significant role in plant regeneration. It is likely that herbivory affected plant succession during this study, especially when eruptions in those populations occurred, but that use was not documented.

## MANAGEMENT IMPLICATIONS

Unfortunately, it was not possible to re-inventory all 53 sites. However, since only two of the sites inventoried in 1983 showed a marked reduction in undesirable cover, it is not likely that there was any substantial change in undesirable cover on other sites. For purposes of vegetation management, we can reasonably say that sites with 5% or less undesirable vegetation cover are potentially controllable with one treatment, and those over 5% will probably require one or more follow-up treatments on any missed stems.

There are 93.8 ha on this ROW. In 1977, 9.8 ha (10%) was less than 1% undesirable cover, 8.6 ha of which was active agriculture. Another 11.8 ha (13%) had 1–5% undesirable cover and 72.2 ha (77%) of the ROW had undesirable cover ranging from 6 to 20%.

Assuming that the resurveyed sites in 1983, 1991 and 1996 are representative and considering the above land use, about 90% of the ROW will need at least minimal treatment on a cyclical basis and about 20–24 ha of the ROW (1/4) will require more extensive treatment. For those sites with less than 5% undesirable cover, low volume foliar or basal treatments are appropriate. Cut/stump is not recommended except at visible road crossings due to the difficulty experienced in obtaining root kill. On sites where undesirable cover exceeds 5%, the first two techniques, plus ground applied high volume foliar with low pressure nozzles and mechanical cutting in standing water, wetlands and residential areas are appropriate. The particular technique employed would depend on plant height, density and species composition along with site sensitivities. Basal, employing a mix of triclopyr and picloram combined with a low volume foliar application to any surviving sprouts, might be the best follow-up techniques. Scotch pine (*Pinus sylvestris*) and white spruce (*Picea glauca*) could be cut and lopped.

Given the array of species (representing all plant groups), the wide density range of undesirable species needing treatment, and various other site factors, all of the above-discussed techniques should be open options for maintenance. For future maintenance, crews should be prepared to do basal, (either standard approach or pre-treat and cut), low volume ground foliar, and cut-and-pile, and tailor the treatment to each site based on density and species composition and site sensitivity factors. Aerial or high volume ground foliar with high pressure nozzles are not appropriate at any sites since undesirable cover is less than 20% and most sites are visible from residences and highways.

## CONCLUSIONS

Tall growing vegetation on utility ROW can be controlled through regular cyclical maintenance. Cyclical maintenance must continue for the life of the facility since there always remains 1–5% or more ground cover of undesirable trees. Positive benefits of this maintenance include greater species diversity in all plant groups other than tall trees and enhanced habitat for a variety of wildlife species. The increased number of rodents and lagomorphs is likely to aid in reducing tree seedlings, though this was not documented in this study.

## ACKNOWLEDGEMENTS

The author is indebted to Richard Pintal who conducted the original vegetation survey; Department of Public Service staff (including my supervisor John Smolinsky) who reviewed the text, my secretaries Cathy Watrobski and Teresa Casey who labored through typing of manuscript and tables; Ed Kautz, biometrician, who provided statistical advice and Niagara Mohawk Power Corporation which granted permission to use its right-of-way for the study.

## REFERENCES

Adams, L.W. and A.D. Geiss. 1981. Roads and roadside habitat in relation to small mammal distribution and abundance. In: Proceedings of the Second National Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State University. p. 54-1 to 55-13.

Bramble, W.C., W.T. Byrnes, and R.J. Hutnik. 1990. Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way. Journal of Arboriculture, 16(5): 21–25.

Bramble, W.C., W.T. 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(2): 99–105

Canfield, C.D., A.R. Berkowitz, J.B. McAninch, M.J. McDonnell, and R.S. Ostfeld. 1994. Vegetation dynamics along utility rights-of-way; factors affecting the ability of shrub and herbaceous communities to resist invasion by trees. Final Technical Report to Empire State Electric Energy Research Corporation, Millbrook, New York, pp. 297–339.

Conover, W.J. 1980. Practical non-parametric statistics, 2nd edn. John Wiley and Sons, New York, pp. 493.

Egler, F.E. 1954. Vegetation science concepts, I. Initial floristic composition, a factor in old-field vegetation development. Vegetatio, 14(6): 412–417.

Jackson, L.W. and R. Pintal. 1978. Natural resources and landuse inventory for public utility rights-of-way in New York. Transactions Northeast Society of Conservation Engineers. White Sulphur Springs, West Virginia, February 28, pp. 1–57.

Jackson, L.W. 1978. A model right-of-way management plan based on a resource inventory of Reynolds Road-Alps 345 kV transmission line in Rensselaer County, New York. Unpublished report. New York State Department of Public Service, Albany, New York, pp. 1–57.

Steele, R.G.D. and J.H. Torre. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, Inc., New York, pp. 366–370.

---

## *BIOGRAPHICAL SKETCH*

***Lawrence W. Jackson***

*New York State Department of Public Service, Three Empire State Plaza, Albany, NY 12223-1350, USA*

Lawrence Jackson is currently employed as an Associate Aquatic and Terrestrial Ecologist with the New York State Department of Public Service in Albany, New York. His primary fields of interest are right-of-way management and wildlife management, particularly white-tailed deer. He has published nearly 50 articles on those two subjects in various journals and as separate unpublished reports over the last 30 years. His BS was obtained in Wildlife Management from the University of Maine and he studied toward an MS in Wildlife Management at Utah State University. Lawrence Jackson has also taken post-graduate courses at Keene State College and the State University of New York at Albany. He is a member of the Weed Science Society, The Ecological Society of America and The Wildlife Society where he currently serves as treasurer in the New York Chapter.

# Application of Integrated Pest Management to Electric Utility Rights-of-Way Vegetation Management in New York State

**Kevin T. McLoughlin**

Integrated Pest Management (IPM) is a process that balances the use of cultural, biological, and chemical procedures for reducing pest populations to tolerable levels. Rather than relying solely on chemicals (or eliminating chemicals completely), IPM seeks to produce a combination of pest control options that are compatible with the environment, economically feasible and socially tolerable. The control of vegetation, i.e., the contemporary management of vegetation, on electric utility line rights-of-way (ROW)[1] readily accommodates itself to an IPM process. This paper describes how the member systems of the New York Power Pool (NYPP) have been actually practicing an IPM strategy for about two decades. However, that strategy can be more appropriately referred to as an Integrated Vegetation Management (IVM) strategy.

*Keywords*: Vegetation management, integrated pest management, cultural procedures, biological procedures, chemical procedures, preventive measures, monitoring, assessment, control measures

## BACKGROUND

In New York State after a forested landscape is cleared, or when a cultivated field is abandoned, the natural vegetation type that will ultimately re-occupy the site and dominate the area will be tall growing trees. When the cleared area is an electric utility Right-of-Way (ROW), these resurgent trees can grow too close to the overhead electric lines. When this occurs, there is the potential for an electrical discharge from the electric line through the air to the tree and then to the ground. This is known as a "line to ground fault or flash-over". The result of a line to ground fault is an instantaneous break in electric service and a dangerous situation on the ground in the immediate vicinity of the high voltage discharge. Therefore, as a matter of public safety and system reliability, utility ROW vegetation managers have a continuing need to preclude the establishment and subsequent growth of those tree species that are capable of growing into or even close to the electrical lines[2]. Utilities ensure that tall growing trees do not interfere with electric lines by carrying out a long term ROW vegetation management program.

## INTEGRATED VEGETATION MANAGEMENT AS AN IPM STRATEGY

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, and chemical

1 Electric utility ROWs are strips of land, from 30 yards to over 300 yards in width, that are used by electric utilities as corridors for the transmission of electric energy.

2 The electrical facilities being discussed herein are for the most part high voltage transmission lines and only those lower voltage distribution lines that have a discernible cleared ROW. There are more than 10,000 circuit miles of overhead transmission lines above 115 kV belonging to the members of the NYPP in New York State. ROW vegetation management under these electric transmission facilities is quite distinct from roadside tree trimming around distribution lines and these street tree pruning operations are not the subject of this paper.

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 (highly selective control techniques often stem specific and including mechanical methods), biological (low-growing plants and herbivory), and chemical (herbicides) controls.

Utilities use three general routine procedures for removing tall growing trees from the ROW: (1) mechanical methods such as mowing and hand cutting with chainsaws, (2) chemical treatments, i.e., the selective application of herbicides and (3) combinations of both mechanical and chemical methods.

Mechanical methods of tree removal alone will clear the ROW of tree stems temporarily. However, employment of these mechanical methods allows trees to physiologically respond by regenerating quickly from the energy reserves contained in their undisturbed root systems. This tree regrowth occurs through such mechanisms as "stump sprouting" and/or in some species "root suckering." This regenerative capacity is characteristic of virtually all hardwoods[3], e.g., maple, beech, birch, aspen, oak, ash, cherry, etc. and will result in the eventual production of many more stems than were originally cut. By drawing upon the food reserves in their undisturbed root systems and through a series of complex compensatory physiological plant responses, the resurgent growth from the remaining portions of the tree (stump and\or roots) is actually enhanced when a tree stem is severed. It is through the production within the plant of naturally occurring stimulatory substances together with the loss of growth inhibitors (caused by the removal of the above ground growth centers) which then exert their influence on the remaining vegetative structure to promote excessive new tree growth. These new, more numerous stems, growing much faster than when left uncut (e.g., five to ten feet the first year after cutting), make subsequent tree removal from the ROW more frequent, laborious, hazardous and costly.

The selective application of herbicides to only the tall growing target tree species can in most instances eliminate completely the resurgent tree growth problem because the herbicide when properly deposited on the target species translocates throughout the tree (including the root system) and arrests all future growth and development, i.e., killing the entire target plant not just temporarily removing the above ground portion. Selective herbicide application involves two general techniques[4]: a basal application to the lower stem of the tree and a foliar application to the leaves. Selective application of herbicides only to the target tree species allows retention of nearly all the desirable low-growing vegetation on the ROW. The elimination of the tall growing trees from the ROW will also encourage the further growth and development of all the indigenous low-growing woody shrubs, herbs (forbs and grasses), ferns, etc. by removing the trees that would otherwise begin to directly compete with and eventually "crowd out" the low-growing species over time. With effective minimally disruptive tree removal, these lower growing desirable plant species will expand into the ROW areas formerly occupied by trees and produce a thick dense plant cover that will discourage the invasion of new tree seedlings and/or the future growth of any remaining tree seedlings. These desirable low-growing plant communities act as the biological controls in this IPM/IVM scenario. The establishment and the preservation of these low-growing plant communities on ROWs serve to reduce over time the amount of work required and cost incurred by the utility to maintain the ROW each treatment cycle while coincidentally diminishing the amount of herbicide necessary for adequate coverage of the target species.

Mechanical and chemical controls are often used together with favorable synergistic results. For instance, a tree is manually cut with a chain saw and the resulting freshly severed stump is treated with a herbicide formulation to prevent resprouting. This procedure removes the immediate physical threat to the overhead electrical line as well as the future tree growth with little disruption to the surrounding desirable plant cover while requiring very limited use of herbicides in a highly efficacious spot application.

## ESSENTIAL ELEMENTS OF AN IPM STRATEGY: ILLUSTRATIONS AND EXAMPLES

IPM programs consist of five basic elements: (1) preventive measures, (2) biological controls, (3) monitoring, (4) assessment, and (5) control measures. These essential elements of a sound IPM/IVM program are illustrated in the following examples.

### Preventive Measures

When the land use of a ROW is altered to preclude the establishment and growth of trees, the utility has little, if any, ROW vegetation management activities to perform. This advantageous situation occurs when a ROW

3 Hardwood is a conventional term for all deciduous (broad-leaved) trees belonging to the botanical class Angiosperm. Softwoods, also commonly referred to as evergreens and conifers, belong to the botanical class Gymnospermae (and are practically confined to the order Coniferae) do not posses this regenerative trait (with one lone exception in the northeast — pitch pine), and once cut below the lowest whorl of live branches will not resprout.

4 Many variations of these two techniques exist.

fee owner or adjacent land owner productively uses the ROW in a manner compatible with the electrical facilities, and this use usurps the potential development of tall growing trees. The most common ROW multiple uses often involve various types of agricultural[5] activities, i.e., crop production, pastures for grazing livestock, and within certain height limitations even Christmas tree plantations and some types of orchards. Those agrarian activities, as well as many other types of allowable industrial, commercial and residential multiple uses, which effectively curtail the opportunity for any tall growing vegetation to become established can thus eliminate completely the burden for any ROW vegetation management by the utility. However, any use of the ROW that allows even one tree capable of growing up into the electrical lines, e.g., hedgerows between cultivated fields, requires due diligence by the utility to prevent an electrical discharge.

**Biological Controls**

One of the principle goals of ROW vegetation management is to promote low-growing relatively stable (long-lived) plant communities, which consist of numerous species of woody shrubs, herbs (forbs and grasses), ferns, etc. on the ROW. These low-growing plant communities are a very desirable ROW accessory in that they inhibit both tree establishment and their subsequent growth by directly competing with the tall growing species for the available site resources (sunlight, water, and nutrients). Thick low-growing plant communities, which hinder tree seed germination and the early development of the undesirable tree seedlings and small tree saplings, act as the biological control agents in this IPM/IVM strategy.

There may even be some indirect biochemical interactions, called allelopathy, occurring among various plants that result in a chemical competition of sorts between certain lower growing desirable ROW species and some of the tall growing tree species. Allelopathy has been defined as the influence of one plant on another via the production of natural growth inhibitors. Currently there exists only a limited understanding of this ability of plants to produce and release phytotoxic substances that can then be translocated to other plants and curtail certain critical physiological functions such as growth and reproduction. These naturally occurring "herbicides" offer yet another potential beneficial aspect of the biological controls in assisting the ROW vegetation manager to curb the spread of the undesirable tall growing trees.

In addition to their immediate benefits to the utility of reducing the undesirable tree population, these low-growing plant communities offer an assemblage of plant species that provide diverse and productive habitat conditions for a wide variety of wildlife, e.g., birds and mammals. Managed ROWs create habitats that provide wildlife food and cover values that are remarkably different, and often surpassing, those of the neighboring forest. Also, this juxtaposition of two different, but complementary plant communities (one perpetually kept in a low-growing condition and the other usually a forest) produces what is known as the "edge effect." This effect enhances wildlife profusion, i.e., abundance and diversity, in the boundary area transition zone (ecotone) between these two distinct habitat types. Some of the new and more numerous wildlife species attracted to these enhanced ROW created habitats provide yet another beneficial function of further reducing tree establishment and growth through their collective herbivory, e.g., browsing by deer and rabbits on young trees, girdling of tree seedlings by voles, and tree seed predation by mice.

**Monitoring**

As explicitly called for in an IPM program, monitoring of the pest population involves the following items:

- Regularly checking the area;
- Early detection of pests;
- Proper identification of pests; and
- Noting the effectiveness of biological controls.

The ROW vegetation managers of the NYPP member systems routinely carry out all of these monitoring activities as an integral part of their electric utility ROW vegetation management programs. Monitoring procedures have been integrated into the Public Service Commission approved "Long Term ROW Management Plans" developed by each member system. Monitoring activities include an evaluation of the previous treatments to determine overall program effectiveness as well as the current condition of the ROW so as to ascertain when the next treatment should occur and by what means. All of these procedures are part of a sound IPM/IVM strategy. ROWs throughout New York State are regularly inspected to determine the height and density of the tall growing target tree species as well as the condition of the lower growing vegetation. Inspection results help determine, to a large extent, the timing and type of ROW vegetation treatment that the utility implements.

These field inspections also serve another important function, i.e., the fulfillment of a quality assessment/quality control (QA/QC) program. This QA/QC component of the ROW vegetation management program provides feedback as to the conduct of the field crews regarding their adherence to the work specifications as well as to determine the longer-term efficacy of the treatments. In addition to the routine utility monitoring, the Department of Public Service staff annually

5 It should be noted that most agricultural pursuits require the use of significant amounts of various pesticides, e.g., insecticides, fungicides, herbicides, etc. on an annual basis. Thus, the total quantities of pesticide applications will often dramatically increase on those ROW areas converted to farm land as compared to the spot treatments of herbicides once or twice a decade by the utility.

inspects the results of the company ROW vegetation management programs to insure compliance with all regulatory mandates.

Identifying the undesirable tree species is a critical component of an IPM/IVM program. With hundreds of species present on a ROW, all vegetation treatment personnel must be sufficiently knowledgeable of plant species to enable them to readily distinguish between target trees to be treated, and all non-target desirable low-growing species to be left as undisturbed as possible. Based upon field inspections, the type of vegetation treatment will also be determined in large part by the distribution and abundance of the lower growing species. For instance, when thickets of shrubs, such as viburnums or dogwoods, are present together with only a few target tree stems, the highly selective stem specific application of herbicides would produce the most acceptable results. The use of mowing or conventional high volume broadcast foliar spraying of herbicides over such a ROW segment containing only a few target species would be quite disruptive to the existing desirable low-growing vegetative cover. Such an ecological disturbance would unnecessarily leave the ROW in a much more open and vulnerable condition thereby actually enhancing the ROW site conditions for the eventual re-establishment of undesirable trees as well as significantly reduce its aesthetic and wildlife values.

### Assessment

Assessment is the process of determining the potential for pest populations (target trees) to reach an intolerable level. For ROW vegetation managers, the most opportune time to eradicate target trees is well before they reach the height of the overhead electrical lines. From an assessment perspective, an effective IPM/IVM strategy needs to: (a) prevent any interruption of electrical service and avoid risk of injury to the public, (b) treat the target species at their optimum height range of five to ten feet or as they emerge from the lower growing plant cover (at this stage they can be conveniently treated with limited amounts of herbicide so as to achieve the highest degree of control possible), (c) cause the removal of the target tree species before they become tall and dense enough to begin to crowd out and adversely alter the composition, structure and density of the desirable lower growing vegetative cover and (d) minimize any direct disruption by the treatments themselves to the existing desirable ROW plants so they continue to occupy the ROW and function as biological controls.

### Control measures

IPM strategy dictates that once a pest population has reached the intolerable level action should be taken. Under an IPM program, chemical pesticides are used as a control measure when no other strategies will bring the pest population back under the economic threshold. In fact, the success of IPM often occurs by waiting until a pest population reaches this threshold and then often hinges on the availability of a pesticide to bring the pest population back under control quickly. For ROW vegetation management the pest population consists of only the target tree species that meet certain critical height[6] characteristics. Only those trees that have emerged from the lower growing plant "canopy" need to be selectively removed; thus many small tree seedlings may remain untreated, submerged within the low-growing plant community on the ROW. Most of these small tree seedlings, left fully submerged within the dense low-growing understory vegetation, will never fully develop into trees as they will succumb to the surrounding competitive pressures of the lower growing desirable vegetation and its associated biotic agents, e.g., animal herbivory. An additional positive attribute of this biological control feature occurs when those few remaining target trees that finally "escape" from the low-growing plant community only do so after a considerably longer time period than would normally happen under relatively (open) unencumbered circumstances. This helps to extend the duration between ROW vegetation treatments.

The choice of treatment technique as well as the explicit mode of application to ensure adequate control of the target tree species are also important aspects of selective ROW vegetation management that uniquely qualifies IVM as an IPM approach. As part of an IVM/IPM program, herbicides are used only to treat individual tree stems or groups of target trees, and no aerial or ground broadcast applications (uniformly spraying the entire ROW) are used in New York State today. Herbicides that are used on ROWs are matched to site specific characteristics and target species, and the products are selected from dozens of commercially available materials based upon various attributes such as efficacy, toxicity, cost, etc. Furthermore, once a specific herbicide is selected for application, its efficacy can

6 This "critical tree height" is determined "electrically" by the distance between the tip of the tree and the overhead electric line with consideration for the voltage of the transmission facility, at any given point on the ROW. The higher the line voltage the more "clearance that is necessary around the conductors which is often refereed to as the wire security zone. For instance a 765 kV line requires about 25 feet whereas a 115 kV line needs about a 10-foot wire security zone. Also, as the voltage of the transmission facility increases the minimum wire distance from the ground likewise increases. The minimum conductor sag at mid-span allowed for a 765 kV line is about 50 feet from the ground whereas a 115 kV line only requires a height of 25 feet from the ground. Finally, the location of the tree on the ROW will determine the distance to the conductors and the resulting allowable maximum tree height that can be tolerated at that particular point. Trees located near the edge of the ROW or close to tall towers can be allowed to grow taller than their compatriots located in the center portions of the ROW near conductor mid-span which is within the area of maximum line sag, i.e., where the line is closest to the ground.

be further enhanced (and its environmental impact minimized) by proper timing and selection of the most suitable method(s) of treatment (including integration with mechanical controls) together with choosing the most appropriate formulation and dosage rate.

The option of non-chemical mechanical clearing of the ROW; by hand cutting with chainsaws, mowing with large machines like a hydro-axe or even using massive earth moving equipment in a stump/soil shearing operation, is an available alternative to provide added protection for those ROW segments occupied by or located close to sensitive land uses or containing special resources. These designated ROW locations can be granted this extra protection through the judicious use of "no spray zones" or "set back distances" which are often referred to as "buffer zones" where herbicide use is not allowed. The determination not to use herbicides can be made by the ROW manager on a site specific basis or through general company policy even when such herbicide use is allowed by law, regulation, and label conditions. The discretion to employ buffer zones as well as the selection of the appropriate set back distances, must be made in a prudent manner since all the mechanical alternatives will inevitably cause an increase in the number and vigor of incompatible tree species on those portions of the ROW so treated. However, the opportunity to employ mechanical clearing of the ROW is an available option for the ROW manager on specifically chosen ROW segments with certain predetermined characteristics that warrant this treatment. Herbicide usage can be restricted in deference to specific notable ROW resources or as a consideration to particularly sensitive land use conditions while still maintaining the overall goals of a sound, long term, and effective IVM program when viewed from a system-wide perspective.

Even in certain ecologically sensitive areas, the selective use of herbicides may be apropos provided the appropriate precautions are taken. For instance, when treating vegetation in or adjacent to designated wetlands, a herbicide with the appropriate characteristics, e.g., an aquatic label, could be selected. However, to assure that virtually no surface water contamination occurs (irrespective of any allowable label statements) buffer zones can be prescribed around streams, lakes, wetlands, and other sensitive water resources. Studies have shown that buffer zones of only 10 to 25 feet can effectively curtail the deposition of airborne spray particles and the movement of the herbicide by runoff into surface water resources. A dense stand of vegetation in the buffer zone will further reduce the linear distance of buffer zone necessary as will very stem specific treatment techniques. Conversely, sparse vegetation in the buffer zone and high volume treatments will increase the distance of the buffer zone required to insure abatement of any herbicide movement. All established NYPP member system specifications for their buffer zones well exceed these threshold conditions.

## ROW CONVERSION

One quite unique aspect of IPM, as applied to the management of ROW vegetation, is the relative long term nature of the desired effects and the timeframe required to assess the consequences of actions taken. Although, mechanical removal of the tall growing trees will physically eliminate the immediate threat to electrical reliability and public safety, this method only serves to perpetuate the long term tree problem and exacerbate future ROW maintenance requirements. Typically, mechanical tree removal will result in the need for more cutting as frequently as every two or at most four years. After several mechanical treatments, i.e., over a number of ROW treatment cycles, the collection of tree stems requiring control can easily increase to over 20,000 stems per acre. Similarly, when a new ROW is cleared and all vegetation is allowed to grow back naturally, the target tree densities will likewise increase to very high levels in only a few years after the initial tree removal operations and prior to any herbicide application.

When herbicides are used over several treatment cycles, the period of time between treatments can usually be elongated to five to eight or more years and concurrently the number of stems to treat each cycle becomes fewer. Herein lies the truly unique aspect of ROW vegetation management from an IPM/IVM perspective; the treatment of vegetation with herbicides must be viewed over the long term to fully grasp the significance of this system in reducing the target tree population that will also reduce the use of chemicals and concurrently increase the effectiveness of the biological controls, i.e., all the lower growing plants that volunteer to occupy the ROW. For example, when a new ROW (or an older ROW that has received only mechanical treatments) is first treated the amount of herbicide needed for proper coverage of the numerous target trees may be in the order of about two to four gallons of concentrate per acre. The following treatment, four to five years later, may require about half that amount because the number of target species has been reduced and the lower growing desirable vegetation is beginning to exert its influence on the ROW vegetation dynamics. The next treatment, in five to six years, will continue this downward trend in herbicide usage until subsequent treatments produce "nearly" a tree-free ROW requiring a minimum of judiciously applied herbicide to produce the desired effect. At this stage the low-growing vegetation is firmly established and offers a relatively stable condition that effectively inhibits the rapid resurgence of trees. However, in order to perpetuate this highly desirable minimum maintenance ROW condition, when new trees begin to emerge (as they most certainly will from the tree seed sources off the ROW) these target trees must still be controlled through the diligent efforts of the ROW vegetation manager to preclude their full development and ultimate dominance over their lower growing associates.

This process of "conversion" from a ROW that is literally filled with trees to one that is dominated by lower growing vegetation with only a few remaining tree stems capable of growing into the overhead electric lines is not a simple one step process, but requires an extended program commitment and adherence to a long range vegetation management plan. Each phase in the ROW conversion process can be quite complex depending in large part upon the target species mix coupled with tree height and density together with the abundance and distribution of the low-growing vegetation as well as other site specific characteristics. As the stem density of the target species is reduced with each passing treatment cycle, the type of treatment chosen can then become more selective. Finally, after several treatment cycles when the ROW is occupied by a low density of target trees and the conversion process virtually completed some continuing herbicide use will still be required, but the focus at this stage shifts to selecting techniques which offer the minimum amount of disturbance to the desirable lower growing vegetation, i.e., the biological controls.

## GENERAL CONSIDERATIONS

The use of herbicides by the NYPP member systems is subject to regulation under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) administered by the U.S. Environmental Protection Agency (EPA) and Article 33 of the New York Environmental Conservation Law (ECL) administered by the Department of Environmental Conservation (DEC). Pursuant to FIFRA regulations, no herbicide may be marketed, distributed, sold or advertised until it is registered by the EPA. After many years of product development, advanced toxicology studies and field testing, the pesticide manufacturers submit to EPA thousands of pages of research data that are compiled into a registration application. From this voluminous registration data, the manufacturer develops a proposed product label that identifies the pest or pests that the product will be effective in controlling and provides complete instructions for correct use, handling, and disposal of the product as well as other information required by FIFRA. In New York State, the DEC has the responsibility for establishing regulations and standards for the registration of pesticides, the certification of pesticides applicators, and all other matters pertaining to pesticide use as well as the responsibility for enforcement of all it's regulations and standards.

Other Federal, State and even local laws and their resulting regulations may impinge on the manner in which ROW vegetation management activities will occur. As mentioned previously, wetland protection requirements can have a pronounced effect on the types of vegetation management techniques chosen. Considerations for the protection of endangered or threatened species and their habitats can similarly become a dominate concern on some ROWs. For instance, the nurturing of the state endangered Karner blue butterfly and its requisite plant, the blue lupine, has resulted in considerable evaluation of selected ROW herbicide use in the preservation and enhancement of the habitat conditions necessary for the survival of this endangered species of butterfly. Even the State requirements for management of river corridors under the Wild and Scenic Rivers Act provides definitions and requirements for IPM. Local ordinances, zoning mandates, as well as property owner concerns may sometimes play a critical role in the selection of ROW vegetation management techniques, e.g., the control of noxious weeds, poisonous plants, and allergy producing pollinators. In some instances compliance with provisions of the Federal Noxious Weed Act may require action on the part of utility ROW vegetation managers to prevent the spread of listed deleterious weeds. For example, the control of infestations of the introduced weed, purple loosestrife, which threatens the biological integrity of North American wetland ecosystems by displacing native vegetation is a goal shared by the electric utility industry with both state and federal environmental agencies.

### Prevention of non-point sources of pollution and storm water discharge requirements

Another important regulatory program that can directly affect the choice of ROW vegetation management practices available under IPM/IVM is found within the authority of the Clean Water Act as amended by the Water Quality Act of 1987 and involves the control of Non-point sources of water pollution along with some aspects of the permit requirements for stormwater discharges for point sources resulting from construction activities. These regulatory programs focus on water quality issues, i.e., the prevention and control of water pollution. In both programs, as they apply to the ROW maintenance situation, the focus is on using management practices to prevent, reduce, minimize or otherwise control the availability, release, or transport of substances that adversely affect surface and ground waters. They both act generally to diminish the generation of potential water pollution emanating from sources on the ROW.

The control of non-point sources of pollution is accomplished through the identification of "best management practices" (BMPs) and their implementation on a site specific basis using best professional judgment and experience. The control of stormwater discharges which can be considered as point sources due to their collection of runoff into a single outlet, e.g., a culvert or ditch, are similarly treated by the requirement to prepare a "Stormwater Pollution Plan" under the auspices of a SPDES (State Pollution Discharge Elimination System) General Permit. This plan essentially enumerates the BMPs that will be used to prevent and/or control polluted runoff from occurring. Neither of these programs imposes effluent limits for specific substances, rather they provide for an effective means of reducing or preventing the impact of pollution generated from land management activities. In addition to the ROW managers primary concern of minimizing pesticide related impacts within the context of an IPM strategy, these two somewhat interrelated regulatory programs broaden the environmental concerns arising from IVM to encompass other pollution control objectives. Thus, both of these clean water related programs can directly influence the decision making process of the ROW vegetation manager and in some cases virtually dictate the menu of treatment choices available.

The most common potential source of pollution arising from a ROW is erosion and the resulting generation of sediment causing siltation in streams and other waterbodies. Sedimentation from all sources is a major water quality degradation issue in New York State. Also, the loss of soil nutrients and their entryway into surface watercourses or groundwater by excessive leaching or as attached to sediment particles is likewise an important water quality concern. Both of these major sources of water pollution can be generated from ROW if bare soils are present or insufficient plant cover occurs. Therefore, in choosing ROW vegetation management techniques, particularly on steep slopes or other areas of high erosive potential, e.g., riparian zones, the ROW vegetation manager must be concerned with their effects on the local hydrology. Vegetative disturbances resulting in bare surfaces or exposed soils and the degree to which vehicular traffic movement occurs causing rutting can become limiting factors in the selection of target tree control methods. For instance, mowing with a hydro-axe on a steep slope or along a streambank could cause erosion by vehicular rutting as well as through denuding the site by excessive removal of vegetation.

The imposition of these regulatory programs to prevent and/or control sources of potential degradation of water resources arising from ROW vegetation management activities results in the following two general precepts: (1) maintain as complete a vegetative cover as possible at all times, and (2) keep exposed soil and any soil disturbance/compaction operations to a minimum especially in critical areas. By keeping these two relatively simple fundamental principles a host of positive attributes can be ascribed to the ROW vegetation management program including: (1) dense low-growing vegetation on the ROW will act as filter strips for the surrounding area thereby decreasing overland flow, increasing soil water percolation and removing pollutants, (2) complete vegetative cover on the ROW will stabilize soils and prevent erosion and sediment transfer, (3) minimizing soil compaction by restricting heavy vehicular traffic on the ROW decreases the amount of surface water generated on a given area and thus reduces the volume of stormwater runoff, and (4) avoidance of any soil disturbance on the ROW will reduce or eliminate the need for amelioration activities that would otherwise be required under these clean water programs to restore the disturbed area to its original slope, soil compaction, ground cover, and hydrologic condition.

## ROW management research

IPM is never a finished or static process. As fresh data become accessible and new knowledge is obtained about the pests in question and the various control treatments available, the specifics and details of the currently acceptable IPM strategies will naturally be altered and thus subject to constant modification. IPM practitioners can aid and abet this dynamic adaptation and improvement process through conducting research on new and promising control strategies. Also needed is the constant reappraisal of existing techniques in order to modify them to produce even more efficacious results. The member systems of the NYPP have individually conducted research into IPM related ROW management matters but even more so collectively, through the auspices of the Empire State Electric Energy Research Corporation (ESEERCO), have collaborated on numerous research projects over a two decade span of time involving many diverse aspects of ROW vegetation management. These studies were conducted on a wide range of subjects and a host of issues important to utility ROW managers in their execution of ecologically sound and cost effective IPM/IVM programs.

Beginning with a literature review in 1973, this extended ESEERCO ROW management research program has included projects on ROW treatment cost comparisons, long term effectiveness, ROW treatment cycles, herbicide fate and mobility, allelopathy, ROW multiple uses, buffer zones, soil compaction and mitigation, repeated mechanical cutting effects on vegetation and costs and the effects of ROW treatments on wildlife. Two recent multi-year studies are only now just concluding; *ROW Vegetation Dynamics* conducted by the Institute of Ecosystem Studies and *ROW Stability* by the State University of New York College of Environmental Science and Forestry. These numerous and diverse research projects have greatly assisted the NYPP/ESEERCO members to focus their ROW Vegetation Management Programs on the most cost effective and least disruptive techniques while allowing them to tailor the research results to their own individual company circumstances. The latest ROW research effort currently being contemplated by the NYPP/ESEERCO member systems involves the establishment of permanent ROW Demonstration areas under which the results of various vegetation management approaches can be continually monitored and evaluated over time and concurrently used as a showcase to portray the evolving ROW vegetation composition as the a function of a specific treatment regime.

## SUMMARY

The overall goal of a utility ROW vegetation management program is to provide for the safe and reliable transmission of electric power in an economic and environmentally compatible manner. This lofty goal translates "on the ground" into the vegetative conversion of a strip of land, i.e., the ROW, often initially found filled with tree saplings to a ROW corridor that harbors mainly a profusion of lower growing species. This goal is currently being achieved in New York State by the implementation of sound IPM/IVM programs at each of the eight member systems of the New York Power Pool. To paraphrase applicable IPM terminology; ROW vegetation managers use multiple tactics to prevent pest (tree) buildups that could endanger electric system reliability and public safety by: monitoring pest (tree) populations, assessing the potential for damage (system reliability, public safety, preservation of the biological controls), and making professional management and control decisions, considering that all pesticides (herbicides) should be used judiciously. ROW management decisions depend in large part upon the mix of target species, the height and density of the dominate individual stems, and the abundance and distribution of the low-growing desirable species. As the number of different target species is reduced and their stem density decreases with each passing treatment cycle, the type of vegetation treatment performed can become more selective with the attendant benefit of reducing the amount of herbicide needed to maintain the ROW. Thus, after several treatment cycles, when the ROW is occupied by a greatly reduced number of target trees, some herbicide use will still be required but the focus now shifts to selecting techniques with the minimum amount of disturbance to the lower growing vegetation.

It should be stressed in closing that this ideal ROW condition of a "minimum maintenance" ROW (composed almost entirely of low-growing plants) to be achieved through the attentive implementation of an IVM/IPM program, is simply just that; minimum not zero maintenance. Although the low-growing plants will help immensely in precluding the growth of trees, due to the pressures of natural plant community succession that ultimately will occur, these voluntary biological controls can never be expected to fully exclude trees over long periods of time from invading the ROW and exploiting their well defined ecological niches. Even after many treatment cycles using herbicides, when the ideal ROW condition is seemingly achieved, if the ROW is left untreated or if mechanical methods are resorted to, the ROW will revert rather quickly to a tree dominated landscape and all the attendant benefits of a stable low-growing mosaic of desirable ROW vegetation will be lost. These attendant benefits include species diversity in an aesthetically pleasing setting with increased wildlife abundance while protecting soil and water quality values.

## REFERENCES


Abrahamson, L.P., C.A. Nowak, P.M. Charlton, and P.G. Snyder. 1992. Cost effectiveness of herbicide and non-herbicide vegetation management methods for electric utility rights-of-way in the Northeast. Niagara Mohawk Power Corporation Project JC28477AGP. Albany, New York, December.

Canham, C.D., A.R. Berkowitz, J.B. McAninch, M.J. McDonnell, and R.S. Ostfeld. 1993. Vegetation dynamics along utility rights-of-way: Factors affecting the ability of shrub and herbaceous communities to resist invasion by trees. ESEERCO Research Report EP85-38. Institute of Ecosystem Studies, Millbrook, New York, December.

Cody, J.B., J.R. Quimby, Vegetation Management on Utility Rights-of-Way An Annotated Bibliography, prepared by State University of New York, College of Environmental Science and Forestry, Applied Forestry Research Institute, AFRI Research Report No. 27, May 1975.

Edwards, D., R. Jacoby, E. McKyes, M. Remington, S. Thew, and E. Thomas. 1990. Soil compaction: A comprehensive retrospective literature review. ESEERCO Research Report EP89-26. December.

Edwards, D., E. McKyes, M.B. Remington, S.F. Thew, and E.D. Thomas. 1996. Soil and crop response to power line construction traffic and shallow and deep tillage in New York State. ESEERCO Research Project EP89-26. March.

ESEERCO Research Project. 1977. Environmental and economic aspects of contemporaneous electric transmission line right-of-way management techniques, Vol. 1: General methods, special studies, discussion of trends, and conclusions. Asplundh Environmental Services, Willow Grove, Pennsylvania. June.

Hadlock, C.R. and D.E. Langseth. 1987. Herbicide residue and mobility study: Existing data and simulation model review, Vol. I. ESEERCO Research Report EP84-8. December.

Hadlock, C.R. and D.E. Langseth. 1987. Herbicide residue and mobility study: existing data and simulation model review, Vol. II. ESEERCO Research Report EP84-8. December.

Hadlock, C.R. and D.E. Langseth. 1987. Herbicide residue and mobility study: Future research plan. ESEERCO Research Project EP84-8. December.

Johnston, P.A., W.C. Bramble, W.R. Byrnes, K.L. Carvell, D.E. White, and H.V. Wiant. 1985. Long-term right-of-way effectiveness. ESEERCO Research Report EP83-15. Environmental Consultants, Inc., Southampton, Pennsylvania. October.

Johnston, P.A., W.C. Bramble, W.R. Byrnes, K.L. Carvell, D.E. White, and H.V. Wiant. 1985. Right-of-way treatment cycles. ESEERCO Research Report EP84-26. Environmental Consultants, Inc., Southampton, Pennsylvania.

Johnston, P.A., W.C. Bramble, W.R. Byrnes, K.L. Carvell, D.E. White, and H.V. Wiant. 1984. Cost comparison of right-of-way treatment methods. ESEERCO Research Report EP80-5. Environmental Consultants, Inc., Fort Washington, Pennsylvania.

Kunzman, M.R. and C. Stevens. 1986. Right-of-way chemical treatments Phase I — Site preparation. ESEERCO Research Project EP85-5. Tree Preservation Co., Inc. Briarcliff Manor, New York. October.

Norris, L.A. 1991. Determination of the effectiveness of herbicide buffer zones in protecting water quality on New York State powerline rights-of-way. ESEERCO Research Report EP89-44. Environmental Consultants, Inc., Southampton, Pennsylvania. August.

Schuler, M.D., P.A. Johnston, and D.E. Holewinski. 1983. The effects of right-of-way vegetation management on wildlife habitat. ESEERCO Research Report EP82-13. Asplundh Environmental Services, Willow Grove, Pennsylvania.
Wright, D.C. 1991. Development of natural growth inhibitors for overhead transmission rights-of-way in New York State, Phase I, Part A: Literature review/search/update. ESEERCO Research Report EP90-14. Brooklyn Botanic Garden, Brooklyn, New York, July.

## *BIOGRAPHICAL SKETCH*

***Kevin T. McLoughlin***
*New York Power Pool, 5172 Western Turnpike, Altamont, New York 12009, USA*

Kevin McLoughlin is presently the Administrator of Land Use & Industrial Waste Programs for the New York Power Pool and the Empire State Electric Energy Research Corporation. He earned his BS and MS Degrees in Natural Resource Management at the State University of NewYork College of Environmental Science & Forestry at Syracuse University. Prior to his current position, he was the System ROW Vegetation Management and Transmission Line Construction Environmental Engineer for the New York Power Authority and served as the Supervisor Natural Resource Management Group. Mr. McLoughlin also had experience with the US Forest Service in Idaho and Arizona.

# Effective Integrated Vegetation Management

Shirley D. Morrow

Integrated vegetation management (IVM) combines manual activities, mechanical tools, and chemical applications with cultural and biological methods to develop a vegetation community that requires minimal maintenance and benefits wildlife and it's habitat. Today, manual, mechanical, and chemical methods are the most often used vegetation management techniques. The primary objective of IVM is to minimize vegetation-related power outages while lowering the cost of future maintenance activities. The IVM plan will identify the environmental constraints and give the vegetation manager flexibility in management methods used. With this, today's vegetation manager must wear many hats—public relations representative, budget manager, environmental steward, and research and development specialist are just a few. Properly executing integrated vegetation management practices using a combination of these methods results in the conversion of rights-of-way to a plant community requiring minimal maintenance activities in the future. Integrated vegetation management balances service reliability, environmental compliance, and customer service while lowering the cost of maintenance over time.

*Keywords*: Vegetation management, rights-of-way, right-of-way maintenance, herbicide, right-of-way management, integrated vegetation management, utility right-of-way management, wildlife habitat

## NEED FOR ELECTRICITY AND MANAGEMENT OF RIGHTS-OF-WAY

### Need for electricity

Historically, the amount of electric power used in the United States has been doubling about every five years. The per capita consumption of electric power has been increasing roughly five times as fast as the population growth (Gardner 1980). There is little doubt that the electrical load growth will continue. The challenge is supplying a growing consumer demand for electricity while minimizing the impact of the necessary generation and transmission facilities on land use, on the environment, and on other aspects of society.

New and complex challenges face the utility vegetation manager due to the steady increase in electrical power demands and the necessity for greatly enlarged, reliable and economical electrical systems. Increasing pressures on urban land use exacerbate the problem. The primary objective of the utility vegetation manager is to minimize the frequency and duration of vegetation-related outages and to lower costs of future maintenance activities.

### Why manage rights-of-way?

The purpose of managing vegetation within utility rights-of-way is to reduce the potential for outages caused when contact with a line causes a fault. A comprehensive management plan provides for ready access for maintenance and emergency repairs. Service can be interrupted by two main types of faults, short circuits and flashovers. Short circuits result when direct contact occurs between an energized conductor and another conductor or a grounded object such as a tree. Flashovers are electrical discharges or currents through the air that result when conductors come too close to each other or to grounded objects such as vegetation (Kroodsma 1985).

The primary means of preventing faults is to maintain adequate clearance between the conductors and other objects such as trees or buildings. Therefore, the utility must remove tall trees within or adjacent to the rights-of-way which could come in contact with the conductors. Such trees are called danger trees.

Vegetation control is a requirement for electric utilities to assure safe and reliable electric service. The control of vegetation, mainly tall trees, in power line rights-of-way is a significant budget item. According to some estimates, U.S. electric utilities have spent over $2 billion dollars annually on vegetation management activities to maintain the reliability of high-voltage power lines. Reliability is of paramount importance. Customers and regulators demand it. The challenge is to weigh the cost against issues such as herbicide use, habitat protection, and public acceptance of herbicide use on rights-of-way. This situation makes vegetation management an extremely complex function. Utilities are dealing with this complexity through integrated vegetation management (IVM). IVM techniques can streamline costs and increase the list of management options in innovative ways.

## INTEGRATED VEGETATION MANAGEMENT

### What is it?

The term Integrated Vegetation Management (IVM) has been around for years but has only recently been picked up and widely used in the utility industry. The term was born out of two other widely used terms: integrated pest management (IPM) and integrated weed management (IWM). IPM is a popular term which is still used in the utility industry but is recognized more widely when discussing insects. IWM is used by the Bureau of Land Management, among others, when discussing the control of noxious weeds and non-indigenous or exotic plants in pasture or rangelands. IVM is a combination of these two terms and refers to the management or control of the "pest", tall growing vegetation which is capable of attaining heights above the designated safety clearance and noxious weeds that electric utilities are required to control.

### Five Management Methods

Integrated management refers to joining together different management methods into a management plan for effective vegetation management on a specific right-of-way. The five management methods are:

1. Manual — the use of physical labor to control vegetation growth such as chain saws, brush hooks, machetes, or shovels.
2. Mechanical — large industrial mowers, tractors, log-skidders, kershaw, and hydro-axe.
3. Chemical — herbicides or growth regulators applied by selective or broadcast methods. Treating selectively the individual plants is the preferred control method.
4. Cultural — the introduction of desirable "low-growing" species onto the rights-of-way.
5. Biological — the introduction of a plant, pathogen, microorganism, etc., that has an allelopathic response to competing vegetation. Allelopathy means the suppression of growth of one plant species by another due to the release of toxic substances. Other biological controls include the use of beetles to control purple loose strife (Malecki 1993) and natural controls such as herbivory (Canham 1994) and seed dispersal by birds and ruminants.

Manual, mechanical and chemical methods are the most often used for IVM. There has been little research conducted on managing rights-of-way biologically. This method would seem innovative and environmentally friendly, but in practice it has usually performed either poorly or inconsistently (Hallmark 1996).

The goal of IVM is to selectively eliminate vegetation which may potentially short circuit overhead conductors on the rights-of-way. This should be accomplished at the lowest possible cost to the consumers with regard for worker safety, protection of public health and with minimal adverse effects on the environment, especially the protection of environmentally sensitive areas. In order for IVM to be effective, the vegetation manager must have a plan.

## THE INTEGRATED VEGETATION MANAGEMENT PLAN

### Goals and objectives

It is important for the utility vegetation manager to define and utilize an IVM plan. Long range goals need to be set. Conversion of the rights-of-way to a managed state is not a one step process, rather it takes years. The primary goal is the control of vegetation on rights-of-way and establishment of standard operating procedures to ensure the maintenance of safe and uninterrupted electric service. Access to the line must also be assured in order to permit routine and emergency line maintenance and operations which are essential to preserve continuity and reliability of service (Holyoke 1988).

One of the first needs is to determine the safety clearance of the line to the vegetation. This step will help determine what species of vegetation need to be controlled and where along the transmission line the control methods need to be used. The transmission of electricity depends on its passage through a conductor hung between structures and insulated from earth by air. The inherent weight of the conductor will produce a sag between structures. Heating and cooling of the conductor will also effect the sag. During times of high loading and high ambient temperature, the sag will increase to a maximum reached at mid-point in the span. If a wind force is then applied at right angles, the conductor will bulge downwind. Since electricity can arc to the ground, especially in moist weather, a minimum acceptable clearance must be established from any conductive object when all of these factors are in force (Gardner 1980).

As part of the IVM plan, a policy of clearance should be prepared and individually tailored for each transmission line or section of line. The policy would specify when and where to remove danger trees. The protection policy must take into consideration the designed sag at maximum loading, conductor blowout under high wind conditions, right-of-way access, climate and site conditions, and the rate of growth and density of the trees present. The condition and age of the individual trees are also important considerations (Gardner 1980).

The IVM plan should include the desired vegetation composition goal for the right-of-way. This would include small trees, shrubs, grassland, wildflower, forb, fern, and moss areas. Objectives might include the percentage of each type of plant material desired in a well managed state along the rights-of-way.

Another objective is to categorize the existing vegetation as either *enhancing* or *endangering* (Gardner 1980). Vegetation can enhance or be compatible to the right-of-way. Vegetation plays an important role in preventing erosion and stabilizing disturbed ground after construction, which is why utility managers should retain as much existing, desirable (low-growing), native vegetation when clearing new right-of-way as possible. Vegetation can soften the harsh outline of lattice towers, mediating the size of structures toward human scale. Vegetation can screen right-of-way cuts in wooded country and it can enhance the habitat and food diversity for wildlife in a given area.

Undesirable (endangering) vegetation extends to a height that encroaches into the safety clearance zone or which may fall into the conductor. This situation would cause forced outages, line tripping, or conductor flashovers. Other types of undesirable vegetation would include poisonous plants and noxious weeds. The control of vegetation requires a two-pronged approach. The manager must manipulate and encourage some species and control, suppress, or eradicate other species, in order to facilitate the safe and continuous operation of the electrical system.

Other objectives that must be considered in developing management strategies include: corporate compliance with pertinent legislation; protection of the natural environment; understanding the social environment including the utility customers; preservation of the clearing design concept; and accomplishment of the whole in the most judicious and economical manner when viewed over the long term. For the most part, neither company management nor the public would question the necessity for some type of vegetation management. The major area of disagreement concerns how control should be obtained and what type of plant communities should be developed and maintained.

## Environmental considerations

The IVM plan should incorporate different management alternatives for different landscape situations. The ideal plan would include the use of manual, mechanical, and chemical methods with cultural and biological methods used if applicable following proven research. The methods chosen should take into consideration the impacts of each method on the environment where it would be applied.

### *Environmental constraints*

The first step is to identify the environmental constraints of the rights-of-way for which the IVM plan is being designed. These constraints may be due to the potential impacts on soil, slope, geology, hydrology, wildlife, land use, visual character, or access that each of the management methods may cause. The IVM plan should take into account all these constraints when selecting the different management methods for the specific areas.

The different management methods have different impacts on each of these environmental elements. Soils need to be considered for their erodability potential from mechanical clearing and their runoff and leaching potential from herbicide methods of vegetation management. Slope will be a factor in erosion and runoff as well as vehicular access for certain management methods. The geology and hydrology of the area should be considered when evaluating herbicide use and for new construction. There could be constraints as to the use of certain persistent and highly mobile chemicals in areas of karst formations or in waterways. There are specific herbicides labeled for use in these areas. Threatened, endangered, or sensitive wildlife may pose a constraint. Certain vegetation management methods could impact identified or designated critical habitat for wildlife as well.

The type of land use in the right-of-way can limit the need for vegetation management and should be an important part of the IVM plan. If the right-of-way could be maintained or converted to a land use such as agriculture, recreation, or open space in a residential development, then it would be specifically maintained according to the dictates of that use.

Visual constraints would include vegetational buffers along roads, trimming in residential areas and landscaping at substations to soften the distinction of the managed vegetation against the adjacent forested areas. Access is essential for maintenance of the right-of-way and the transmission line itself, but it should be designed for limited access by utility vehicles only with access controls to limit trespassing by other off-road vehicles.

After the constraints and existing conditions are identified, then the method or methods of vegetation management for each section of transmission line may be developed. This in part will be dictated by the existing vegetation. The plans should integrate as many management methods as possible to allow for adoption of the most appropriate one on a given site thus minimizing any impacts.

### *The use of herbicides*

Research has been conducted over the last ten years to evaluate the impacts of herbicide use on utility rights-of-way compared to the impacts of the more widely used manual and mechanical methods. Recent research has shown a justification for selective herbicide use which includes: (1) better regulation of stem density and plant composition (Niering 1986); (2) improved wildlife habitat (Bramble and Byrnes 1985, 1992a&b, 1994, 1996); (3) economics (Abrahamson 1991); (4) erosion control; and (5) less noise and air pollution. Other factors which help justify selective herbicide use are the more intensive herbicide regulations These include improvements in chemical formulations, environmental monitoring where herbicides are used, and state testing and certification for chemical applicators. These studies have produced ways to help reduce negative environmental impacts and support incorporation of herbicide use as a major component in the IVM plan.

There may be some areas which are herbicide sensitive. These herbicide sensitive areas are those sections of right-of-way where herbicides may only be used with extreme caution, only specific herbicides used, or may not be used at all due to environmental constraints. Constraints may be due to the presence of threatened or endangered species, critical habitat, potable water, or karst geology which usually has direct exposure to groundwater. Herbicide sensitive areas should be identified specifically in the IVM plan.

Although herbicides are used on agricultural land, forests, rangelands, and aquatic areas, as well as utility rights-of-way, they have been met with mixed reactions by the public. There are a number of non-ecological problems associated with the use of herbicides. These problems are people oriented, and can be classified as either external or internal in origin. The external problems stem from adverse publicity concerning pesticides which has cast herbicides in a bad light. This problem of condemnation of all pesticides is due in large part to the inability of people to differentiate between the comparatively safe herbicides and the highly toxic insecticides which receive the majority of unfavorable publicity (Roberts 1969).

Unfortunately, the chemical manufacturers and users have only had limited experience in counteracting this negative image that all pesticides are dangerous. The industry has occasionally intensified the negative perception of herbicides through the inept usage of chemical weed and brush killers and untimely applications of herbicides on rights-of-way. These practices are internally oriented problems but have decreased in the recent years.

The innovative use of herbicides including new technology and methods has evolved significantly over the past decade as utilities have learned more about the alternatives to traditional methods of right-of-way management. Herbicide use can create public concern and become a public relations nightmare when improperly applied or mismanaged.

### Basic elements of the plan

A clear understanding of the biological processes is absolutely necessary before an adequate attempt can be made to prepare the necessary long term plans for properly managed corridors through effective IVM. There must be an understanding of the dynamics of plant succession that lead to the current vegetation mix, as well as the succession that will take place after clearing. Managers must also understand what the impacts of each method of control have on the stability of plant communities.

Stabilized community development with shrub species has been shown to be possible and demonstrated to be ecologically and economically attractive (Niering 1986). Selective vegetation control benefits wildlife habitat for many species of animals by encouraging plant communities that provide food and cover. This result has been proven through the multitude of research done by Bramble and Byrnes (1985, 1992a&b, 1994, 1996).

The IVM plan should also be designed to maintain acceptable appearance of the rights-of-way and to minimize erosion by allowing the development of low shrubs and ground cover. The low shrubs and ground cover will inhibit the re-establishment of target tree species. The result is to reduce the area which needs to be managed, thus reducing the management costs.

The plan must include the determination as to which vegetative species are considered enhancement and which are endanger. The plan should cover all environmental constraints and all management methods to be used under all conditions along the line. With herbicide use, the specific herbicides for each specific use area and for each specific vegetation species should be identified, as well as mixing rates and application methods.

Maps are a critical element of any IVM plan. They should show the existing vegetation, what the vegetation management method is for any given area, and all environmentally sensitive areas, especially herbicide sensitive areas. Maps could easily be created using a Global Positioning System (GPS) to locate the different vegetation species along the rights-of-way. The data could then be entered into a Geographic Information System (GIS) for map creation. The GIS system could also contain data on environmental constraints, soil types, slope, transmission line information, roads, waterways, and any other information associated with the rights-of-way.

The plan should also include the duration between treatments of the unwanted vegetation. Duration is dependent on vegetation growth rates which would vary with vegetation type, topography, climate, and precipitation. The vegetation control method would also affect the determination of the treatment frequency.

## HOW TO MEASURE SUCCESS

The success of any vegetation management program is dependent on a comprehensive, accurate, open information network. Large utilities have increasingly sophisticated management requirements. They should form a Vegetation Management Group with the appropriate staff which would specifically be responsible for vegetation management (Gardner 1980).

A utility vegetation program on rights-of-way must also embrace a variety of support services. The program should examine interactions between vegetation management and other related issues. The execution of a safe, economic, environmentally and aesthetically sound program should be built on the foundation of good planning and justifiable rationale. This rationale must be understood by both political and civil government and the public at large, if the underlying objectives of vegetation management are to be attained without social and misguided environmental disruption.

The success of the IVM plan will be realized after a few years of integrated management which will lead to a more stable vegetation community of desirable species which in turn leads to less intensive maintenance with less frequency. Low intensity, less frequent maintenance will lead to less disturbance of the rights-of-way and less environmental impacts. The end result is less cost to the utility.

## RECOMMENDATIONS AND CONCLUSIONS

### Recommendations

There has been an increase in research and discussion on effective IVM over the years. Although some New England states and New York have been practicing IVM for up to 20 years, there is a long way to go before the practices are known, understood, and accepted everywhere. Areas of continued research and development that are needed include:

- safer herbicides both to humans and the environment
- better methods and equipment for application of herbicides
- human and environmental safety implications of vegetation management
- multiple use potentials for rights-of-way
- restoration and biological controls; and
- improved communication.

Another important recommendation for utilities is to compare their vegetation management program to the industry standard. The Environmental Protection Agency (EPA) has a Pesticide Environmental Stewardship Program (PESP). PESP's goal is to reduce the risk and use of pesticides in the environment (Hallmark 1996). Three principles of this program are identified as follows.

- Use low-toxicity herbicides. They pose the lowest possible health hazard to the applicator and the environment.
- Use low-volume application techniques. They reduce the volume of product used on an acre-by-acre basis and target the undesirable species.
- Continue to develop new technologies that improve ease of application, reduce worker exposure, and improve delivery of the product to the target plant.

Education and training are two of the most important aspects of the program. The EPA and several states offer training programs to educate applicators and vegetation managers about PESP principles and the development of IVM programs. There is a need for more training programs, not only to educate applicators and utility vegetation managers, but also the public. The public needs to be kept up-to-date on the newest technologies, new and safer herbicides, new research, and changes in the risk assessment data about the herbicides. Intensified educational programs should be designed to acquaint the public with the true nature of herbicides and to dispel the misconception that growth regulators and insecticides are the same. Such information will help to relieve the public's fear of the unknown and give them a better understanding of herbicides in general.

### Conclusion

The utility vegetation manager is faced with new and complex challenges due to the steady increase in electrical power demands. IVM practices combine manual, mechanical, and chemical methods of vegetation management with biological and cultural methods where applicable. The manager should identify the existing conditions and environmental constraints of the right-of-way and then tailor an IVM plan to produce a stabilized, low-growing, vegetation community.

The IVM plan should give the vegetation manager the option of different method of vegetation control under different circumstances for optimum vegetation management. This should achieve the goal of minimizing the frequency and duration of vegetation related outages and provide environmental benefits while lowering the costs of future maintenance activities.

## REFERENCES

Abrahamson, L.P., C.A. Nowak, E.F. Neuhauser, C.G. Foreback, H.D. Freed, S.B. Shaheen, and C.H. Stevens. 1991. Cost effectiveness of utility rights-of-way vegetation management treatments: initial clearing. Journal of Aboriculture, 17(12): 325–327.

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(2): 99–105.

Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1994. Nesting of breeding birds on an electric utility line right-of-way. Journal of Arboriculture, 20(2): 124–129.

Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1992a. Breeding-bird population changes following right-of-way maintenance treatments. Journal of Arboriculture, 18(1): 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. Journal of Arboriculture, 18(6): 316–321.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1985. Effects of a special technique for right-of-way maintenance on deer habitat. Journal of Arboriculture, 11(9): 278–284.

Canham, C.D., A.R. Berkowitz, J.B. McAninch, M.J. McDonnell, and R.S. Ostfeld. 1994. Vegetation dynamics along utility rights-of-way; factors affecting the ability of shrub and herbaceous communities to resist invasion by trees. Final Technical Report by Institute of Ecosystem Studies to Central Hudson Gas & Electric Corp. Milbrook, New York. pp. 297–339.

Electric Power Research Institute. 1995. Vegetation management by electric utilities: use of herbicides and other methods. Environmental Management Services, Waupaca, Wisconsin.

Gardner, M.R. 1980. Models for vegetation management on electrical utility transmission rights of way. Pestology Centre, Simon Fraser University, British Columbia, Canada.

Hallmark, S. 1996. IVM, a competitive tool. Electric Perspectives. May/June, 1996.

Holyoke Power. 1988. Right-of-way vegetation management plan (VMP) for Western Massachusetts Electric Company, Holyoke Water Power Company, and Holyoke Power and Electric Company for years 1989 through 1993.

Holyoke Power. 1988. Part A: Right-of-way vegetation management plan (VMP) for Western Massachusetts Electric Company, Holyoke Water Power Company, and Holyoke Power and Electric Company for years 1989 through 1993.

Kroodsma, R. and J. Van Dyke. 1985. Technical and environmental aspects of electric power transmission. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Malecki, R.A., B. Blossey, S.D. Hight, D. Schroeder, L.T. Kok, and J.R. Coulson. 1993. Biological control of purple loose strife. Bioscience, 43(10): 680–686.

Niering, W A. and G.D. Dreyer. 1986. Evaluation of two herbicide techniques on electric transmission rights-of-way: development of relatively stable shrublands. Environmental Management, 10(1): 113–118.

Roberts, H.A. 1969. A wildlife manager's view of herbicide use on the right-of-way. Proceedings of the Northeast Weed Control Conference, 23: 291–293.

## *BIOGRAPHICAL SKETCH*

***Shirley D. Morrow***

*Burns & McDonnell, 9400 Ward Parkway, Kansas City, MO 64114, USA*

Shirley D. Morrow is an Environmental Scientist/ Landscape Designer for Burns & McDonnell. She specializes in writing environmental assessments for transmission line routing projects, writing construction erosion and sedimentation control plans, designing vegetation management plans, and landscape design. She has a BS in Zoology from Fort Hays State University, BLA (Bachelors in Landscape Architecture) from Oklahoma State University, MS in Environmental Science from Oklahoma State University, and a Turf Management degree from University of Guelph, Ontario, Canada. Shirley Morrow is pursuing certification as an erosion and sedimentation control professional and is interested in research pertaining to the use of yard waste compost for erosion control.

# Optimal Management Strategies for Biodiversity Within a Powerline Right-of-Way

**Matthew C. Perry, Peter C. Osenton, Frederick W. Fallon, and Jane E. Fallon**

Management techniques used to control vegetation along a new 8.5 km (5.3 mile)-long powerline right-of-way located at Patuxent Research Refuge are being evaluated to identify changes in habitat that affect wildlife. Techniques include: complete mow, strip mow, low volume foliar spray, selective basal spray, and tree topping. One hundred and one bird species were recorded during line transect sampling along the right-of-way. Fifteen species were recorded in numbers greater than ten individuals per visit in at least one season of the year. Nine species of mammals were trapped in live traps during the study and four other mammal species were observed but not captured. Twelve species of amphibians and six species of reptiles were trapped in pitfall or funnel traps. Differences in the distribution of species seemed to be related to the physical and hydrological features of the right-of-way. Although no major differences in the distribution of wildlife species resulted from the vegetation management, differences are expected in the future as vegetation differences become more pronounced. Data from this study will be of value to resource managers attempting to provide optimal habitat for biodiversity.

*Keywords*: Right-of-way, powerline, biodiversity, wildlife, birds, mammals, amphibians, reptiles, traps

## BACKGROUND AND JUSTIFICATION

A 500 kilovolt (kV) overhead transmission line was constructed by the Baltimore Gas and Electric Company (BGE) during 1994–95 as a portion of the last section of a 500 kV loop around Washington, D.C. One segment of this line goes through the North Tract of the Patuxent Research Refuge (Patuxent) adjacent to an existing 230 kV transmission line constructed in 1972.

Patuxent is a 5120 ha (12,800 acre) research facility within the U.S. Department of the Interior and located in Laurel, Maryland. Within the North Tract, the right-of-way for both lines is approximately 8.5 km (5.3 miles) long, 92 m (300 ft) wide, and covers 77 ha (193 acres).

BGE has a regional responsibility to maintain a reliable transmission system utilizing cost-effective and environmentally compatible vegetation management techniques. These techniques traditionally include mowing, cutting with chain saws, and herbicide spraying of vegetation.

A management plan has been developed by BGE in cooperation with Patuxent to provide optimal utilization of the right-of-way by wildlife. Site-by-site prescriptions were outlined to guide construction activity and to provide a baseline for future maintenance practices. Several of the practices referenced in the Management Plan are experimental and in some instances must remain flexible during the maintenance process to meet the changing needs of both parties. The long-term commitment by BGE to manage this diverse area provides an excellent opportunity to implement a concurrent research project to evaluate the various wildlife management and right-of-way maintenance techniques that are incorporated in the plan, while assessing general cost-effectiveness.

Although land management to increase wildlife populations has been conducted for many years (Leopold 1933), rights-of-way for powerlines have been seriously managed for wildlife only since the 1950s (Foster 1956; Egler 1957; Niering 1958). Much of the interest in right-of-way management was due to the availability of herbicides following World War II (Egler 1949), and numerous studies have been conducted to evaluate the various ways to use these chemicals to

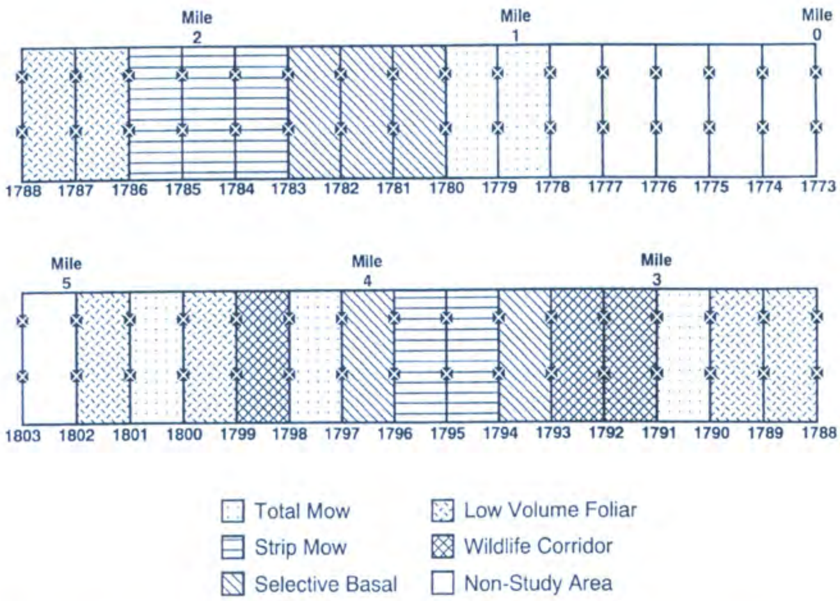



Fig. 1. Distribution of habitat management techniques used on the 8.5 km (5.3 mile)-long BGE powerline right-of-way as described in the Management Plan.

control unwanted vegetation (Niering and Goodwin 1974; Bramble and Byrnes 1983). Dreyer and Niering (1986) evaluated basal and stem foliar herbicides to selectively eliminate tall-growing trees, and selective basal spraying has been effectively used at Patuxent since 1968 on another powerline right-of-way managed by Potomac Electric Power Company (Fleming 1989; Obrecht et al. 1991).

The relationship between powerline right-of-way vegetation and the diversity and abundance of wildlife has been documented in many areas (Gysel 1962; Longcore 1971; Anderson 1979; Meyers and Provost 1979). The influence of landscape-level factors on wintering bird populations in powerline and pipeline right-of-ways was evaluated by Pearson (1993). The present study evaluates five major management techniques for right-of-ways in regard to wildlife biodiversity. The objective of this study was to inventory and evaluate seasonal distribution of wildlife (avian, mammalian, and herpetofauna) within the BGE right-of-way in all habitat management types.

## TECHNIQUES

The powerline right-of-way was divided into various segments of management techniques based on the Management Plan and using aerial photographs of the area provided by BGE. Five major habitat management techniques have been identified in the Plan and will be studied in this project (Fig. 1). They include two types of mowing (strip and total), two herbicide applications (selective basal spraying and low volume foliar spraying), and establishing wildlife corridors. Wildlife corridor is a special technique obtained by leaving trees but limiting their height by topping. It simulates the forest on both sides of the right-of-way and, therefore, acts as a corridor for wildlife moving through the area.

The study area for this project included the area between Tower 1778 to 1802 (Table 1). All management techniques were conducted on a tower to tower basis to

**Table 1. Habitat management techniques used along the BGE powerline right-of-way including the wildlife trapping locations**

| Tower number | Management techniques | Trap site |
|---|---|---|
| 1778–1779 | total mow | |
| 1779–1780 | total mow | |
| 1780–1781 | selective basal spray | |
| 1781–1782 | selective basal spray | |
| 1782–1783 | selective basal spray | |
| 1783–1784 | strip mow | yes |
| 1784–1785 | strip mow | |
| 1785–1786 | strip mow | |
| 1786–1787 | low volume foliar spray | |
| 1787–1788 | low volume foliar spray | |
| 1788–1789 | low volume foliar spray | |
| 1789–1790 | low volume foliar spray | yes |
| 1790–1791 | total mow | |
| 1791–1792 | wildlife corridor | yes |
| 1792–1793 | wildlife corridor | |
| 1793–1794 | selective basal spray | |
| 1794–1795 | strip mow | |
| 1795–1796 | strip mow | |
| 1796–1797 | selective basal spray | yes |
| 1797–1798 | total mow | yes |
| 1798–1799 | wildlife corridor | |
| 1799–1800 | low volume foliar spray | |
| 1800–1801 | total mow | |
| 1801–1802 | low volume foliar spray | |

Some sections where mowing is the major management technique also include some spraying to control vegetation in areas hard to reach with mowing equipment.

assist in the experimental design. A total of 24 sections occurred within the study area. The techniques included strip mow (5 sections), total mow (5 sections), selective basal spraying (5 sections), low volume foliar spraying (6 sections), and wildlife corridor (3 sections). In addition to the five major habitat management types that will be studied intensively, there is one area that will not be sampled intensively because of lack of replication. This area is a 2-acre study site used by BGE staff. The study site is being evaluated using a variety of vegetation management techniques to determine effects on the diversity of the plant community (pers. comm., T. Benassi).

Bird populations were sampled in 1995–96 by line transect sampling (Burnham et al. 1980) along a transect established near the center of the right-of-way. Sampling was conducted by two observers once a week throughout the year starting at one hour after sunrise. Starting points for both observers were different and were varied so that all habitats were sampled evenly with regard to time of day. The locations of all singing males heard during the breeding season were recorded on a map so that territories could be plotted and breeding bird density could be estimated in each habitat type.

In addition to the transect survey, two additional surveys were conducted for nocturnal birds. Woodcock were surveyed at dusk (19:00–21:00) on one night in both March and April. Five observers familiar with the nuptial call and flight of woodcock were assigned to separate sections of the study site so that all areas were surveyed simultaneously. Whip-poor-wills were surveyed similarly between 21:00 and midnight during one night in both May and June. Moon phase was considered when selecting days to increase probability of hearing whip-poor-wills, which are more vocal during full moon phases.

Mammals were live-trapped during July to November 1996 in one site for each habitat type (Table 1). Sherman live traps (for small mammals) and Hav-a-Hart box traps (for medium-sized mammals) were operated for four trap-days per month. All mammals were released on site. Sand plot track sites were established to record tracks of animals that are difficult to trap, such as fox and deer (Perry and Giles 1970). The location of wildlife observed or killed by hunters within right-of-way were recorded and data assembled by staff at the Hunter Control Station in the North Tract of Patuxent.

Amphibians and reptiles were sampled at one site for each habitat type with the use of 15.4 m (50 ft) drift fences. Two pitfall traps were constructed at each end and two funnel traps were placed in the middle on each side of the drift fence. At each of the five sites there were two drift fences: one parallel and one perpendicular to the right-of-way. This arrangement was done to intercept animals moving across or along the right-of-way. Each pitfall and funnel trap was numbered to better understand movement of animals by knowing on which side of the fence each animal was caught. The drift fence trapline was opened for five months (July–November 1996) for four trap-days each month. Captured animals were identified, counted, and released on site.

## RESULTS

Avian surveys conducted between 1 July 1995 and 30 June 1996 recorded a total of 101 species within the right-of-way or along the edge. Only three species (fish crow, Kentucky warbler, and rock dove) were seen along the edge but not in the right-of-way, whereas, 33 species were seen within the right-of-way but not along the edge (Table 2). However, it should be noted that birds seen or heard along the edge would have been further from the observer, therefore, creating an obvious sampling bias.

The eastern towhee had the highest frequency of occurrence (318) followed by the field sparrow (208) and the common yellowthroat (201). The field sparrow had the highest numbers per visit (17.2) followed by the eastern towhee (15.5) and eastern bluebird (13.4). Twelve species that had a total frequency of occurrence of over 100 but were not seen in large numbers (<10 birds/visit), included American goldfinch, blue jay, Carolina chickadee, Carolina wren, gray catbird, indigo bunting, northern flicker, prairie warbler, red-bellied woodpecker, red-eyed vireo, tufted titmouse, and white-eyed vireo (Table 2).

Three American woodcock were heard conducting courtship displays along the powerline right-of-way during a special survey on 25 March 1997. One whip-poor-will was heard singing in the woods adjacent to the right-of-way on 15 June 1996. These two species were surveyed to fully evaluate diversity of avian species seen or heard in the powerline right-of-way habitats.

Several avian species, whose populations are typically low in this area of Maryland, were seen during this study. The Lincoln's sparrow is a migrant in Maryland and was seen twice along the powerline right-of-way during one of the fall surveys. The Henslow's sparrow, although not recorded on the surveys for this study, was observed in May on the North American Migration Count on the BGE powerline right-of-way. The hermit thrush was seen in shrub habitat during the winter on seven different occasions.

Seasonal differences in numbers of species using the right-of-way were observed. The greatest number of species recorded in the right-of-way was 80 observed in the fall (Table 3). However, along the edge, the most species seen or heard was 57, which was recorded in the spring. This is most likely the result of many migrating songbirds using the forest in the spring when males can be heard singing.

Fifteen species of birds were seen in numbers greater than 10 birds per visit during at least one season (Table 4). Eight of these species were seen in greatest numbers

**Table 2. Avian species* recorded during 31 visits along BGE powerline right-of-way during 1 July 1995 to 30 June 1996**

| Species | Freq* | ROW sum (avg.) | Edge sum (avg.) | Species | Freq* | ROW sum (avg.) | Edge sum (avg.) |
|---|---|---|---|---|---|---|---|
| Acadian Flycatcher | 17 | 4 (0.1) | 15 (0.4) | House Sparrow | 1 | 4 (0.1) | |
| Accipiter Species | 1 | 1 (0.0) | | House Wren | 75 | 95 (3.1) | 1 (0.0) |
| American Crow | 80 | 80 (2.6) | 117 (3.8) | Indigo Bunting | 106 | 149 (4.8) | 10 (0.3) |
| American Goldfinch | 138 | 228 (7.4) | 30 (1.0) | Kentucky Warbler | 9 | | 9 (0.3) |
| American Kestrel | 5 | 8 (0.3) | | Least Flycatcher | 1 | 1 (0.0) | |
| American Redstart | 12 | 13 (0.4) | 2 (0.1) | Lincoln's Sparrow | 2 | 2 (0.1) | |
| American Robin | 73 | 193 (6.2) | 61 (2.0) | Louisiana Waterthrush | 1 | 1 (0.0) | |
| American Tree Sparrow | 2 | 2 (0.1) | | Magnolia Warbler | 4 | 4 (0.1) | 1 (0.0) |
| Baltimore Oriole | 5 | 3 (0.1) | 1 (0.0) | Mourning Dove | 45 | 42 (1.4) | 14 (0.5) |
| Belted Kingfisher | 1 | 1 (0.0) | | Northern Cardinal | 85 | 102 (3.3) | 22 (0.7) |
| Blackpoll Warbler | 1 | 1 (0.0) | | Northern Flicker | 110 | 71 (2.3) | 64 (2.1) |
| Blk-throated Blue Warbler | 3 | 3 (0.1) | | Northern Mockingbird | 48 | 58 (1.9) | |
| Blk-throated Green Warbler | 2 | 4 (0.1) | | Northern Parula | 31 | 6 (0.2) | 25 (0.8) |
| Black Vulture | 1 | 2 (0.1) | | Northern Waterthrush | 1 | 1 (0.0) | |
| Black-and-white Warbler | 34 | 11 (0.3) | 27 (0.9) | Orchard Oriole | 10 | 17 (0.5) | |
| Blue-gray Gnatcatcher | 43 | 42 (1.4) | 11 (0.4) | Ovenbird | 73 | 6 (0.2) | 86 (2.8) |
| Blue Grosbeak | 55 | 80 (2.6) | 1 (0.0) | Palm Warbler | 8 | 12 (0.4) | |
| Blue Jay | 171 | 89 (2.9) | 179 (5.8) | Pileated Woodpecker | 40 | 1 (0.0) | 29 (0.9) |
| Blue-winged Warbler | 1 | 1 (0.0) | | Pine Warbler | 28 | 25 (0.8) | 21 (0.7) |
| Broad-winged Hawk | 4 | 4 (0.1) | | Prairie Warbler | 132 | 190 (6.1) | 9 (0.3) |
| Brown Creeper | 1 | 1 (0.0) | | Purple Finch | 1 | 1 (0.0) | |
| Brown-headed Cowbird | 92 | 126 (4.1) | 18 (0.6) | Red-bellied Woodpecker | 113 | 13 (0.4) | 121 (3.9) |
| Brown Thrasher | 41 | 40 (1.3) | 8 (0.3) | Red-breasted Nuthatch | 17 | 7 (0.2) | 22 (0.7) |
| Canada Goose | 4 | 1 (0.0) | | Red-eyed Vireo | 140 | 46 (1.5) | 178 (5.7) |
| Carolina Chickadee | 136 | 125 (4.0) | 71 (2.3) | Red-shouldered Hawk | 8 | 3 (0.1) | 3 (0.1) |
| Carolina Wren | 105 | 116 (3.7) | 21 (0.7) | Red-tailed Hawk | 38 | 32 (1.0) | 2 (0.1) |
| Cedar Waxwing | 13 | 25 (0.8) | 1 (0.0) | Rock Dove | 3 | | 1 (0.0) |
| Chestnut-sided Warbler | 4 | 3 (0.1) | 1 (0.0) | Rose-breasted Grosbeak | 4 | 4 (0.1) | 1 (0.0) |
| Chimney Swift | 6 | 3 (0.1) | | Ruby-crowned Kinglet | 20 | 33 (1.1) | 1 (0.0) |
| Chipping Sparrow | 36 | 63 (2.0) | 4 (0.1) | Ruby-thr. Hummingbird | 10 | 8 (0.3) | |
| Common Grackle | 16 | 295 (9.5) | 10 (0.3) | Savannah Sparrow | 1 | 1 (0.0) | |
| Common Yellowthroat | 201 | 334 (10.8) | 8 (0.3) | Scarlet Tanager | 44 | 14 (0.5) | 35 (1.1) |
| Cooper's Hawk | 4 | 4 (0.1) | | Sharp-shinned Hawk | 5 | 3 (0.1) | |
| Dark-eyed Junco | 69 | 380 (12.3) | 1 (0.0) | Song Sparrow | 84 | 227 (7.3) | |
| Downy Woodpecker | 45 | 30 (1.0) | 19 (0.6) | Summer Tanager | 28 | 28 (0.9) | 10 (0.3) |
| Eastern Bluebird | 179 | 415 (13.4) | 32 (1.0) | Swainson's Thrush | 2 | 1 (0.0) | 2 (0.1) |
| Eastern Kingbird | 86 | 126 (4.1) | 4 (0.1) | Swamp Sparrow | 31 | 73 (2.4) | 2 (0.1) |
| Eastern Phoebe | 27 | 27 (0.9) | 7 (0.2) | Tree Swallow | 1 | 1 (0.0) | |
| Eastern Towhee | 318 | 482 (15.5) | 67 (2.2) | Tufted Titmouse | 173 | 107 (3.5) | 151 (4.9) |
| Eastern Wood-Pewee | 59 | 12 (0.4) | 52 (1.7) | Turkey Vulture | 16 | 9 (0.3) | 2 (0.1) |
| Empidonax Species | 7 | 6 (0.2) | 1 (0.0) | White-breasted Nuthatch | 54 | 6 (0.2) | 52 (1.7) |
| European Starling | 3 | 5 (0.2) | 1 (0.0) | White-crowned Sparrow | 2 | 2 (0.1) | |
| Field Sparrow | 208 | 532 (17.2) | 9 (0.3) | White-eyed Vireo | 133 | 136 (4.4) | 20 (0.6) |
| Fish Crow | 2 | | 1 (0.0) | White-throated Sparrow | 63 | 195 (6.3) | |
| Golden-crowned Kinglet | 10 | 13 (0.4) | | Winter Wren | 1 | 1 (0.0) | |
| Gray Catbird | 171 | 211 (6.8) | 34 (1.1) | Wood Thrush | 62 | 1 (0.0) | 83 (2.7) |
| Great Crested Flycatcher | 19 | 2 (0.1) | 20 (0.6) | Yellow-bellied Sapsucker | 2 | 2 (0.1) | |
| Great Horned Owl | 1 | 1 (0.0) | | Yellow-billed Cuckoo | 33 | 1 (0.0) | 40 (1.3) |
| Hairy Woodpecker | 9 | 6 (0.2) | 2 (0.1) | Yellow-breasted Chat | 78 | 88 (2.8) | 1 (0.0) |
| Hermit Thrush | 18 | 19 (0.6) | 6 (0.2) | Yellow-rumped Warbler | 8 | 4 (0.1) | 9 (0.3) |
| Hooded Warbler | 42 | 6 (0.2) | 40 (1.3) | Yellow-throated Vireo | 32 | 5 (0.2) | 32 (1.0) |
| House Finch | 78 | 117 (3.8) | 16 (0.5) | | | | |

*Frequency represents the total number of times the species was recorded at least once within any section during any visit. The sum is the total individuals for all sections and all visits. Average is total divided by 31 visits.

**Table 3. Bird species recorded by season* along the powerline right-of-way (ROW) and the edge of the right-of-way during 31 visits, 1 July 1995 to 30 June 1996**

| | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| ROW | 51 | 80 | 31 | 67 |
| Edge | 46 | 46 | 14 | 57 |

*Summer = 1 June–15 August; Fall = 16 August–30 November; Winter = 1 December–29 February; Spring = 1 March–31 May.

**Table 5. Species of mammals captured* on the BGE powerline right-of-way between 16 July and 15 November 1996**

| Species | Total | Sites | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Opossum | 1 | | | 1 | | |
| Masked Shrew | 5 | | 3 | 2 | | |
| Short-tailed Shrew | 4 | | 1 | | 3 | |
| Eastern Mole | 1 | | 1 | | | |
| Raccoon | 8 | | 4 | 3 | 1 | |
| White-footed Mouse | 17 | 5 | 1 | | 5 | 6 |
| Meadow Vole | 2 | | 1 | | | 1 |
| Pine Vole | 2 | 1 | | | | 1 |
| Vole species | 1 | | | | 1 | |
| Meadow Jumping Mouse | 5 | | 4 | | 1 | |
| Total | 46 | 6 | 15 | 6 | 11 | 8 |

*Trap days totalled 300 for Hav-A-Hart traps, 487 for Sherman live traps, and 100 for drift fences.

per visit in the fall and five species were seen in greatest numbers per visit in the summer (Table 4). The American robin was seen in greatest numbers per visit in the winter and the brown-headed cowbird was recorded in greatest numbers in the spring.

Nine species of mammals were captured within the right-of-way during the five-month trapping period (16 July–15 November 1996) in live box traps or pitfall traps (Table 5). The white-footed mouse (*Peromyscus leucopus*) was the most numerous of the small mammals captured. The meadow jumping mouse (*Zapus hudsonius*) and the masked shrew (*Sorex cinereus*) were most frequently captured at Site 2, the wettest of the five sites.

Among the medium-sized mammals only one opossum and eight raccoons were captured. The trapping rate for these two species is about half that obtained on forested wetlands during another study at Patuxent Research Refuge (Perry et al. 1996). The gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes fulva*), and groundhog (*Marmota monax*) were seen along the right-of-way during the study, but were not captured. White-tailed deer (*Odocoileus virginianus*) were frequently seen on the powerline right-of-way and numerous deer were killed by hunters along the right-of-way during the hunting season. The right-of-way has traditionally been a preferred hunting area for hunters at Patuxent.

Twelve species of amphibians were captured within the powerline right-of-way during the trapping period (16 July–15 November). The green frog (*Rana clamitans*) was the most frequently captured amphibian representing 45 of the total 145 individual amphibians that were captured (Table 6). The chorus frog (*Pseudoacris triseriata*) was heard calling during the spring in numerous wet areas of the right-of-way, but was not captured in the traps. Three species of salamanders, but only five individuals, were captured.

Six species of reptiles and 16 individuals were captured within the right-of-way (Table 6). All reptiles

**Table 4. Most abundant species of birds recorded along the BGE powerline right-of-way during visits 1 July 1995 to 30 June 1996***

| Species | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| American Goldfinch | 61 (10.2) | 125 (10.4) | 3 (0.8) | 39 (4.3) |
| American Robin | 6 (1.0) | 71 (5.9) | 98 (24.5) | 18 (2.0) |
| Brown-headed Cowbird | 28 (4.7) | 3 (0.3) | | 95 (10.6) |
| Common Grackle | | 295 (24.6) | | |
| Common Yellowthroat | 86 (14.3) | 126 (10.5) | | 122 (13.6) |
| Dark-eyed Junco | | 254 (21.2) | 64 (16.0) | 62 (6.9) |
| Eastern Bluebird | 45 (7.5) | 270 (22.5) | 35 (8.8) | 65 (7.2) |
| Eastern Kingbird | 69 (11.5) | 10 (0.8) | | 47 (5.2) |
| Eastern Towhee | 110 (18.3) | 242 (20.2) | | 130 (14.4) |
| Field Sparrow | 68 (11.3) | 263 (21.9) | 61 (15.3) | 140 (15.6) |
| Gray Catbird | 71 (11.8) | 92 (7.7) | | 48 (5.3) |
| Indigo Bunting | 75 (12.5) | 29 (2.4) | | 45 (5.0) |
| Prairie Warbler | 72 (12.0) | 14 (1.2) | | 104 (11.6) |
| Song Sparrow | | 144 (12.0) | 15 (3.8) | 68 (7.6) |
| White-thr. Sparrow | | 172 (14.3) | 16 (4.0) | 7 (0.8) |

*Numbers are total individual birds seen and average number per visit in parentheses. The 31 visits included 6 in summer (1 June–15 August), 12 in fall (16 August–30 November), 4 in winter (1 December–29 February), and 9 in spring (1 March–31 May).

**Table 6. Species of amphibians and reptiles captured* on the BGE powerline right-of-way between 16 July and 15 November 1996**

| | Total | Sites | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Amphibians | | | | | | |
| Marbled Salamander | 1 | 1 | | | | |
| Red-spotted Newt | 2 | | | 2 | | |
| Four-toed Salamander | 2 | | | 2 | | |
| American Toad | 23 | 6 | 2 | 6 | 7 | 2 |
| Fowler's Toad | 21 | 16 | | 1 | 2 | 2 |
| Northern Cricket Frog | 23 | | 15 | 4 | 2 | 2 |
| Spring Peeper | 4 | | 1 | 3 | | |
| Bull Frog | 3 | | | 1 | 1 | 1 |
| Green Frog | 45 | 2 | 27 | 6 | 5 | 5 |
| Wood Frog | 1 | | | | 1 | |
| Southern Leopard Frog | 8 | | 2 | 2 | 3 | 1 |
| Pickerel Frog | 12 | 1 | 1 | 3 | 7 | |
| Total | 145 | 26 | 48 | 30 | 28 | 13 |
| Reptiles | | | | | | |
| Northern Fence Lizard | 4 | | | 2 | 2 | |
| Six-lined Racerunner | 1 | 1 | | | | |
| Five-lined Skink | 1 | | | | 1 | |
| Eastern Garter Snake | 5 | | | 4 | | 1 |
| Eastern Hognose Snake | 2 | 2 | | | | |
| Northern Black Racer | 3 | 1 | | | 1 | 1 |
| Total | 16 | 4 | 0 | 6 | 4 | 2 |

*Trap days for drift fence was 100.

captured are species typically found in fairly dry habitat, which was where they were captured within the powerline right-of-way. No reptiles were captured at site 2, the wettest site.

## DISCUSSION

The number of bird, mammal, amphibian, and reptile species captured or seen along the powerline right-of-way during 1995–96 reflects the relatively high biodiversity of these habitats created and maintained by humans. Although no rare species of animals were recorded during this study, more intensive sampling of the flora and fauna in the future will probably increase the species list and possibly add some rare species to the list. The present management plan conducted by BGE in cooperation with the Patuxent Research Refuge staff is flexible and can easily accommodate the protection of unique habitats or rare species.

Because the right-of-way was managed with similar techniques (mostly low volume foliar spray) from 1971 to 1995, there were few differences in the wildlife species composition or numbers among the 26 sections. The construction activities during 1994–95 also caused the right-of-way habitat to be homogenous. Differences noted among wildlife species observed or captured were best explained by physical or hydrological features, rather than with management techniques.

Past management practices of the right-of-way also appeared to be a factor in wildlife numbers. For example, robin abundance during winter seemed strongly associated with large numbers of holly (*Ilex opaca*) trees on the powerline right-of-way (especially between towers 1786–1790). Holly trees, which have been protected for many years on the right-of-way, provide excellent food and cover to the robin, a major winter migrant in Maryland.

In future years, as the new techniques result in more alteration of the right-of-way habitats, it is expected that greater differences in the wildlife populations will be recorded. Attention should be given, however, to species that may potentially affect biodiversity adversely in the future. The brown-headed cowbird was recorded in high numbers in the spring and this could reflect high parasitism on other species whose populations are low. Nest surveys should be conducted to evaluate the extent of the problem and if nest parasitism differs among management techniques. The exotic vine, mile-a-minute weed (*Polygonum perfoliatum*), was found in several areas of the right-of-way and could increase its distribution in the future. This fast growing plant has the potential to spread throughout the right-of-way and negatively impact native plants.

When differences in habitats and species using these habitats are noted in future years as a result of management techniques, researchers will be able to advise the managers of optimum techniques to use to benefit biodiversity along the right-of-way. The findings of this study indicate that the powerline right-of-way is providing habitat to a large number of wildlife species and, hopefully, will continue to be important habitat in the future.

## ACKNOWLEDGEMENTS

Assistance with the experimental design was obtained from T. Benassi, C. Devine, J. Hatfield, and H. Obrecht, III. Establishment of drift fences was done by B. Bauman, J. Cowan, S. Pugh, and S. Tanata. Assistance with data entry and analyses was obtained from G. Gough, L. Loges, and C. Sibrel. K. Boone and L. Lammons assisted with graphics and word processing. Drafts of this manuscript were reviewed by D. Dawson, H. Obrecht, T. Benassi, and two anonymous reviewers.

## REFERENCES

Anderson, S.H. 1979. Changes in forest bird species composition caused by transmission-line corridor cuts. American Birds, 33(1): 3–6.

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.

Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Journal OF Wildlife Management, 72: 202.

Dreyer, G.D. and W.A. Niering. 1986. Evaluation of two herbicide techniques on electric transmission rights-of-way: development of relatively stable shrublands. Environmental Management, 10(1): 113–118.

Egler, F.E. 1949. Right-of-way maintenance by plant community management. Aton Forest, Norfolk, Connecticut. 19 pp.

Egler, F.E. 1957. Right-of-way and wildlife habitat: progress report. Transaction North American Wildlife Conference, 22: 133–144.

Fleming, W.J. 1989. Vegetation management technique enhances wildlife habitat on powerline right-of-way. Research Information Bulletin, U.S. Fish & Wildlife Service Number 89-09.

Foster, C.H.W. 1956. Wildlife use of utility right-of-way in Michigan. MS Thesis, University of Michigan, Ann Arbor, Michigan.

Gysel, L.W. 1962. Vegetation and animal use of a power line right-of-way in southern Michigan. Quarterly Bulletin Michigan Agriculture Experiment Station, 44(4): 697–713.

Leopold, A. 1933. Game Management. Scribners, New York. 481 pp.

Longcore, J.R. 1971. Powerline right-of-way. American Birds, 25(6): 997–999.

Meyers, J.M., and E.E. Provost. 1979. Bird population responses to a forest-grassland and shrub ecotone on a transmission line corridor. In: Proceedings Second Symposium on Environmental Concerns in Rights-of-Way Management. Ann Arbor, Michigan.

Niering, W.A. 1958. Principles of sound right-of-way 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(4): 784–795.

Obrecht, H.H., III, W.J. Fleming, and J.H. Parsons. 1991. Management of powerline rights-of-way for botanical and wildlife value in metropolitan areas (abstract). In: Wildlife Conservation in Metropolitan Environments. L.W. Adams and D.L. Leedy, eds. National Institute for Urban Wildlife.

Pearson, S.M. 1993. The spatial extent and relative influence of landscape-level factors on wintering bird populations. Landscape Ecology, 8: 3–18.

Perry, M.C. and R.G. Giles. 1970. Studies of deer-related dog activity in Virginia. Proceedings of the Southeastern Association of Game and Fish Commissioners, 24: 64–73.

Perry, M.C., C.B. Sibrel, and G.A. Gough. 1996. Wetlands mitigation: Partnership between an electric power company and a federal refuge. Environmental Management, 20(6): 933–939.

## *BIOGRAPHICAL SKETCHES*

***Matthew C. Perry***

*Patuxent Wildlife Research Center, 11410 American Holly Drive, Laurel, MD 20708, USA*

B.S. University of Rhode Island; M.S. Virginia Polytechnic Institute, PhD University of Maryland.

***Peter C. Osenton***

*Patuxent Wildlife Research Center, 11410 American Holly Drive, Laurel, MD 20708, USA*

B.S. University of Rhode Island.

***Frederick W. Fallon***

*Patuxent Wildlife Research Center, 11410 American Holly Drive, Laurel, MD 20708, USA*

A.B. Harvard College, M.S. University of South Florida, Ph.D. University of South Florida.

***Jane E. Fallon***

*Patuxent Wildlife Research Center, 11410 American Holly Drive, Laurel, MD 20708, USA*

B.S. Michigan State University, M.S. Ohio State University.

# Evaluation of Blade Plowing and Dot-Grid Herbicide Techniques for Selective Control of Trees on Electric Transmission ROWs

**Charles E. Rowell, Kenneth W. Farrish, and James M. Dyer**

A research project was conducted to evaluate two alternative vegetation management techniques on electric transmission line ROWs. The objective of the research was to test techniques that showed promise at reducing tree numbers on the ROWs, while maintaining maximum biodiversity of non-tree vegetation. Blade plowing and a dot-grid herbicide technique, using hexazinone and picloram, were evaluated on four study sites in Mississippi, Louisiana and Arkansas. The sites were selected to represent a range of soil types: loamy, upland, Coastal Plain soils; loess soils; poorly drained, fine textured, alluvial soils; and gravelly upland soils. Blade plowing, conducted during early summer, was deemed moderately effective (54–71% reduction in tree numbers) on the loess soils and on the upland, loamy and gravelly soils, and ineffective (14% reduction in tree numbers) on the poorly drained, fine textured, alluvial soils. The dot-grid herbicide technique was effective on the loess soils (78% reduction in tree numbers), performed poorly (28–54% reduction) on the upland loamy and gravelly soils, and was ineffective on the poorly drained, fine textured, alluvial soil. Biodiversity of non-tree vegetation remained high under both treatments when compared to the control (mowed-only). The cost of the dot-grid herbicide technique was considerably higher than that of the blade plow technique. The results of the work indicate that the blade plow technique has potential on upland sites as a selective, non-chemical approach to tree control on electric transmission ROWs. Further evaluation of blade plowing without preceding mowing is needed.

*Keywords*: Vegetation management, rights-of-way, biodiversity, dot-grid herbicide application method, tree control, blade plow, woody root management, hexazinone, picloram

## INTRODUCTION

Vegetation management of electric transmission rights-of-ways (ROWs) has become more complex in recent years due to tightened maintenance budgets and heightened environmental awareness by the public. In the southern United States, vigorous tree resprouting following traditional rotary mowing is the major vegetation management problem (Arner, Glover, Hartley, and Huntly 1987). ROWs that are managed with only mowing commonly contain tree stem populations of several thousands per hectare (Rowell, Farrish, and Dyer 1993). Earlier work by the authors showed that ROWs in forested areas contain large numbers of woody roots that can support tree resprouting (Farrish, Rowell, and Dyer 1993). By simply mowing or burning the above ground sprouts, these root systems are left intact to again send up new, vigorous sprouts (Arner, Glover, Hartley, and Huntly 1987). Frequent mowing is thus required to control the vegetation. Therefore, the logical approach for longer term control should involve disrupting these root systems, not just the above ground sprouts. Broadcast herbicide applications, while very effective at reducing tree populations, are not selective only against trees (Glover and Arner 1993). Perennial herbaceous and shrub species that have aesthetic and wildlife values are also impacted. Also, the very high numbers of tree stems on these ROWs, up to 10,000 per hectare, makes selective spot application of herbicides impractical without first greatly reducing their numbers.

In 1992, Entergy Corporation funded a research project that sought alternative approaches to control unwanted tree sprouts on ROWs. The goal of the work was to test cost effective techniques that would reduce populations of tall tree species on ROWs, while maintaining maximum biodiversity of the remaining plants. A technique used in that project that showed promise in achieving that goal was blade plowing. In this technique, a 3 m (10 ft) wide blade plow is pulled in a horizontal plane between 20–25 cm (8–10 in) beneath the surface of the soil. The plow creates very little surface disturbance, yet shears off woody roots in its path. Tree sprouts are thus deprived of deeper, moisture supplying roots and many succumb. A large percent of smaller plants with shallower root systems survive the treatment. Upland Coastal Plain ROW sites in north Louisiana that were blade plowed during the summer growing season had reductions in tree stem populations of over 50% and vigor of surviving trees was also reduced (Rowell, Farrish, and Dyer 1993).

The results of the 1992 study were encouraging enough to warrant a follow-up study that began in 1994. The first objective of this study was to test the blade plow treatment on a variety of soil types to better gauge its effectiveness and its limitations. A second objective of this study was to determine if blade plowing effectiveness was limited by season of application. The third objective of the study was to evaluate a dot-grid herbicide technique, developed for forestry applications, for ROW vegetation management. In this technique, soil active herbicides (hexazinone and picloram) are applied in concentrated spots (dots) on a grid pattern. Large root systems, like those of trees, have a high probability of intersecting one or more of these dots and thereby receive a lethal dose of chemical. Smaller plants have a smaller probability of intersecting the dots, so the method is indirectly selective against trees. Of course, the grid spacing and application rate are important variables in this method. Overall browning of the ROW would be reduced from that of broadcast herbicide application and surviving perennial herbaceous and shrub species would maintain wildlife and aesthetic values.

## METHODS

### Study sites

Four study sites were used in this study. The first of these was located near Natchez, Mississippi. Soils of the area were derived from loess parent materials and surface textures were silt loam. The topography was rolling and the soils are highly erodible. Forest vegetation consisted of mixed upland hardwoods, dominated by oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), black locust (*Robinia pseudoacacia*), and hickories (*Carya* spp.). The soils are fertile and well drained. Consequently, tree growth in the ROWs is even more vigorous than on other landscapes of the region. Vegetation on the 30 m (100 ft) wide ROW used in the study had not been cut for three years and the trees were large, ranging up to 8 cm (3 in) in diameter, and numerous. The ROW was managed on a three-year cutting cycle. This site was used in the study because we believed that the larger trees and highly erodible soils might present challenges to the treatments.

The second site used in the study was located near Ferriday, Louisiana. Soils of this area were derived from fine textured, alluvial deposits on the Mississippi River floodplain. Surface soil textures were silty clay, and the soils were poorly drained. The topography was nearly level. Forest vegetation consisted of mixed bottomland hardwoods, dominated by oaks (*Quercus* spp.), green ash (*Fraxinus pennsylvanica*), and elm (*Ulmus* spp.). Vegetation on the 30 m (100 ft) wide ROW used in the study had not been cut for two years. The ROW was managed on a two-year cutting cycle. Tree sprouts and seedlings were numerous, but not large. This site was used in the study because we believed that the fine textured, poorly drained soils might pose challenges to the treatments, specifically pulling the blade plow with a reasonable size tractor. In addition, soil active herbicides, such as hexazinone, used in the dot-grid method often are less effective on fine textured soils where the high clay fraction ties up much of the chemical. Consequently, we wanted to test the methods limitations for ROW vegetation management on such a site.

The third site used in the study was located near Malvern, Arkansas. Soils of the area were derived from loamy parent materials with high coarse fragment (gravel) content. Surface soil textures were loamy sand to sandy loam and the soils were well drained. The topography was undulating. Forest vegetation consisted of mixed pine-hardwoods, dominated by shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and hickories (*Carya* spp.). Vegetation on the 30 m (100 ft) wide ROW had not been cut for two years. The ROW was managed on a two-year cutting cycle. The high coarse fragment content of the soil might pose challenges for use of the blade plow and a sizable pine seedling component on this study site offered an opportunity to evaluate the effectiveness of both treatments on these trees.

The fourth site was located near Grambling, Louisiana. Soils of the area were derived from loamy, Coastal Plain, parent materials. Surface textures were loamy sand to sandy loam, and the soils were well drained to moderately well drained. The topography was undulating. Forest vegetation consisted of mixed pine-hardwoods, dominated by loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and hickories (*Carya* spp.). Vegetation had not been cut on the 30 m (100 ft) ROW for one year. The ROW was managed on a two-year cutting cycle. This site was used in the study because it was typical of extensive areas of upland in the region. A sizable pine seedling component on this site also offered an opportunity to evaluate the effectiveness of both treatments on these trees. In addition, a blade plow seasonal trial study was conducted on this site.

### Treatments

Three replications of three treatment plots (30 × 15 m) were established at each site. One of the treatment plots in each replication was treated with the dot-grid herbicide application in mid May. At the Natchez and Ferriday sites, a 3 ml volume of undiluted hexazinone (Velpar L) was placed at each grid intersection of 0.9 × 1.8 m (3 × 6 ft) pattern using a syringe chemical applicator. This amounted to a volume of 18.5 liters chemical per hectare (1.9 gal per acre). At the Malvern and Grambling sites, the hexazinone volume was reduced to 2 ml per spot (12 liters per hectare), but a 1 ml volume (6 liters per hectare) of undiluted picloram (Tordon K) was added to each spot in an attempt to control pine seedlings on these sites in addition to the hardwoods. A fire plow was used on the forest edge of each of the dot-grid herbicide plots to sever lateral forest origin roots to prevent off ROW tree damage from the soil active herbicides.

In late June, vegetation on all of the plots was cut with rotary mowers to about a 10 cm height. In early July, one of the treatment plots in each replication was blade plowed with a Savannah Forestry Equipment blade plow pulled with a rubber treaded, Caterpillar Challenger tractor. The plow was set to run at between 20 and 30 cm (8–10 in) beneath the soil surface and it produced minimum surface disturbance. Blade plow passes were slightly overlapped to avoid having untreated areas within the plots. The remaining three plots at each site served as a mowed-only control.

Six similar plots were established at the Grambling site in the Spring of 1994 to test seasonal effects on blade plowing effectiveness. Three of the plots were mowed and then blade plowed in early May. The remaining three plots served as a mowed-only control.

### Vegetation measurements

Data were collected for this study in the summer of 1995, approximately one year after the treatment applications. At Natchez, MS, Grambling, LA, and Malvern, AR, tree sprouts and seedlings within two 4.6 m (15 ft) radius circular measurement plots in each treatment plot were identified by genus, stems were counted, and measured for height (tallest stem only). Data at Ferriday, LA study site was obtained from two 2.3 m (7.5 ft) radius circular measurement plots per treatment plot. Tree heights were not measured at this site. The term "tree stems" is used to include all root suckers, stump sprouts and individual stems of seedlings on an area basis. The term "tree numbers" refers to the number of clumps of tree stems that are assumed to belong to the same individual plant. The total number of stems was divided by the number of trees to determine the number of stems per individual tree. Other plants (woody and herbaceous) were quantified (number of species and occurrence) on two 1 $m^2$ sample plots located randomly in each of the treatments and the control.

Plot values were converted to a per hectare basis. Cumulative tree height index of the dominant stems was calculated (Miller, Zutter, Zedaker, Edwards, and Newbold 1995). This value serves as an index of undesirable tree total growth. Shannon/Weaver (1949) biodiversity indices were calculated from data obtained from each of the 1 $m^2$ non-tree sample plots. The randomized block statistical design was analyzed using Analysis of Variance and Duncan's mean separation test.

## RESULTS AND DISCUSSION

### Blade plow treatment — site trials

*Natchez site*

The blade plow treatment was effective at the Natchez site where it reduced tree numbers and tree stem numbers by 59 and 70%, respectively, compared to the mowed-only control (Table 1). Surviving tree heights after one year were not significantly different on the blade plow treated plots, while cumulative height was reduced 55% due to the reduced number of trees.

The main concern about use of the blade plow technique at this site was whether it would promote soil erosion on these highly erodible loess soils. The machinery worked very well as configured on this site, in spite of the large tree stumps encountered, and little scalping of the surface occurred. The greatest exposure of mineral soil with this technique occurs when the plow first enters the soil and when it is withdrawn from the soil, although seldom were these areas observed to extend more than about two meters. Since we used small plots in this study, the plow was inserted and removed from the soil many more times than it would be in an operational setting, and yet no signs of soil erosion were evident. Within a few weeks, all bare mineral soil patches were naturally revegetated.

Estimated costs of the blade plow treatment were reasonable. Operation costs were estimated at about \$109 per hectare (\$44 per acre). This estimate, however,

**Table 1. Measured tree parameters on treatment plots at the Natchez site**

| Treatment | Trees ($ha^{-1}$) | Stems per tree | Height of tallest stem (cm) | Cumulative height (km) |
|---|---|---|---|---|
| Control | 3527a | 2.46a | 108.4a | 3.82a |
| Blade plow | 1445b | 1.81a | 117.9a | 1.71b |
| Dot-grid herbicide | 761b | 1.83a | 79.9b | 0.61b |

Means in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test.

did not include equipment transportation costs or other overhead costs. Also, because of the limitations of our small plot time-study, operational costs may be quite different.

*Ferriday site*

The blade plow treatment was much less effective at the Ferriday site, where tree numbers and tree stem numbers were reduced by only 14 and 29%, respectively, compared to the mowed-only control (Table 2). The differences were not statistically significant. A possible explanation for the reduced effectiveness of the treatment on the site may be due to the wet nature of the soils. These poorly drained, silty clay textured soils remained moist during most of the growing season. If moisture stress following blade plowing is necessary to cause mortality of treated trees, lack of such stress may be the reason that blade plowing was less effective on this site. Consequently, these results indicate that blade plowing may not be a viable treatment on ROWs in wetland landscapes.

Another reason for using this site in the study was to determine if the equipment would have difficulty with the poorly drained, fine textured soils. The blade plow functioned normally in the heavy clay and the Challenger tractor pulled the equipment easily.

**Table 2. Measured tree parameters on treatment plots at the Ferriday site**

| Treatment | Stems per plot | Stems (×1000) (ha$^{-1}$) |
|---|---|---|
| Control | 8.98 | 40.9 |
| Blade plow | 7.49 | 28.9 |
| Dot-grid herbicide | 6.06 | 30.1 |

**Table 3. Measured tree parameters on treatment plots at the Grambling site**

| Treatment | Trees (ha$^{-1}$) | Stems per tree | Height of tallest stem (cm) | Cumulative height (km) |
|---|---|---|---|---|
| Control | 8828a | 2.19a | 74.2a | 6.55a |
| Blade plow | 3298b | 1.57b | 65.2b | 2.15b |
| Dot-grid herbicide | 6139a | 2.06a | 74.8a | 4.59a |

Means in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test.

**Table 4. Measured tree parameters on treatment plots at the Malvern site**

| Treatment | Trees (ha$^{-1}$) | Stems per tree | Height of tallest stem (cm) | Cumulative height (km) |
|---|---|---|---|---|
| Control | 10629a | 1.93a | 94.4a | 10.03a |
| Blade plow | 4896a | 1.39b | 69.7c | 3.41b |
| Dot-grid herbicide | 7611a | 1.58a | 81.6b | 6.21a |

Means in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test.

*Grambling site*

The blade plow treatment was effective at the upland Grambling site where tree numbers and tree stem numbers were reduced by 71 and 76%, respectively, compared to the mowed-only control (Table 3). However, height growth of the surviving trees was unaffected. Cumulative height growth was reduced by 70%, due to the reduced number of trees. The reduction in tree numbers at this site due to blade plowing was comparable to results of work done by the authors at similar upland sites in the area conducted in previous years (Rowell, Farrish, and Dyer 1993).

*Malvern site*

The blade plow treatment was only moderately successful at the upland Malvern site, where tree numbers and tree stem numbers were reduced by 54 and 67%, respectively, compared to the mowed-only control (Table 4). Height growth of surviving trees was also reduced by 26%. Cumulative height growth, integrating reduction in both tree numbers and height growth, was reduced by 66%. The effectiveness of the blade plow treatment at the Malvern site may have been compromised because the plow, as configured, did not perform as well in this soil. The high coarse fragment content of the soil caused the large coulter blade that rolls ahead of the plow to frequently ride up on the surface, pulling the blade plow from the soil. Savannah Equipment personnel believed that the device could be reconfigured to operate better in these types of soils.

## Blade plow treatment — seasonal trial

The blade plow treatment seasonal trial conducted at the Grambling site in July reduced tree numbers by 77%, compared to the mowed-only control, while the same treatment conducted in early May reduced tree numbers by only 8% (Table 5). This dramatic difference in performance of the blade plow treatment may be due to differences in moisture stress placed upon the trees immediately following the treatment. Soil moisture in early May was relatively high and evapotranspiration rates were relatively low. Trees treated in early May may have had time to reestablish deeper root systems before the onset of dry, hot summer weather. These results coincide with those of the summer blade plowing at the Ferriday site, which also indicated that success of the blade plow treatment may depend on having periods of moisture stress immediately after the treatment.

**Table 5. Blade plow seasonal trial (spring and summer) tree stem numbers at the Grambling site**

| Treatment | Stems ($ha^{-1}$) |
|---|---|
| Spring | 9079a |
| Summer | 2095b |

Values in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test.

## Dot-grid herbicide treatment — site trials

*Natchez site*

The dot-grid herbicide treatment using hexazinone was very effective at the Natchez site, where tree numbers and tree stem numbers were reduced by 78 and 84%, respectively, compared to the mowed-only control (Table 1). In addition, height growth of surviving trees was reduced by 27%, and cumulative height growth was reduced by 84%. The effectiveness of the dot-grid technique at this site may be due in part to the larger size of the trees on the ROW at the time of treatment. It had been three years since the ROW vegetation had been cut on the fertile site and the trees were much larger than at the other sites.

The cost of the treatment was relatively high at about $432 per hectare ($175 per acre) for herbicide alone. Application in the trial was conducted manually with a syringe gun. This is very labor intensive. If the method was developed further for ROW vegetation management, automated application equipment would need to be developed.

*Ferriday site*

The dot-grid herbicide treatment was ineffective at the Ferriday site. Tree numbers were not reduced at all, and tree stem numbers were reduced by only 27%, compared to the mowed-only control (Table 2). The failure of this technique at Ferriday is attributed to at least three factors. First, the Velpar herbicide is tied up by the clay fraction in soils. The high clay content of this soil may have tied up enough of the chemical as to render the application ineffective. A second possible reason for the failure of the technique at this site may be due to the fact that the ROW was inadvertently mowed by regular maintenance contractors only two weeks after treatment, instead of five weeks after treatment as planned in the research. This early mowing of the tree shoots may have diminished uptake of the herbicide as well. Finally, the trees were much smaller on this site at the time of treatment than at the Natchez site and this may have also diminished herbicide uptake.

*Grambling site*

The dot-grid herbicide treatment was only moderately effective at the Grambling site, with a reduction of tree numbers and tree stem numbers of 54 and 43%, respectively, compared to the mowed-only control (Table 3). Tree height growth was reduced by 17% and cumulative height growth was reduced by 38%. The quantity of hexazinone used per dot at this site was reduced from three to two ml. Picloram was added at the rate of one ml per dot. This change in chemical usage was made in an attempt to also remove unwanted pine seedlings from the ROW at this site which hexazinone does not control. While hexazinone has long been used in the dot-grid technique in forestry applications, we and Dow Chemical representatives were unaware of any previous use of the Tordon product (picloram) in this technique, and its use in this manner may not be effective on either pine or hardwood components. Also, the trees on this site were relatively small at the time of treatment since the ROW was mowed the previous year, and this may have diminished herbicide uptake. If further evaluation is considered for the dot-grid technique for ROW vegetation management, chemical trials, rate determinations, grid pattern spacing studies, and determinations of optimum grow-out periods will be needed.

*Malvern site*

The dot-grid herbicide treatment was not very effective at the Malvern site with a reduction in tree numbers and tree shoot number of only 28 and 41%, respectively, compared to the mowed-only control (Table 4). Tree heights were reduced by 14% and cumulative tree height was reduced by 38%. The herbicide treatment was conducted at this site in the same manner as at Grambling, with a reduced volume of Velpar L and the addition of Tordon K, due to the presence of unwanted pine seedlings. The reasons for the relatively poor performance of the technique at this site are probably the same as those outlined for the Grambling site.

## Treatments and plant biodiversity

Biodiversity of remaining vegetation was not significantly impacted by either the blade plow treatment or the dot-grid herbicide treatment when compared to mowing alone (Table 6). However, the total woody component generally decreased under both the treatments as the tall

**Table 6. Biodiversity indices (Shannon–Weaver Function[1] (in decits)) by treatment for the Natchez, Ferriday, Grambling and Malvern sites**

| Site | Treatment | | |
|---|---|---|---|
| | Control | Blade plow | Dot-grid herbicide |
| Natchez, MS | 1.84 | 1.86 | 1.89 |
| Ferriday, LA | 1.67 | 1.76 | 1.66 |
| Grambling, LA | 1.76 | 1.92 | 1.89 |
| Malvern, AR | 1.73 | 1.70 | 1.76 |

[1]Shannon-Weaver (1949).

tree species component was decreased. Thus the project achieved its stated goal of significantly reducing the tall tree species components of the vegetation community on the ROWs while maintaining maximum plant biodiversity.

## CONCLUSIONS

Results of the blade plow treatment conducted in the summer on the upland sites were generally encouraging, with reductions in tree numbers ranging between 54 and 71% compared to mowed-only control; and reductions of tree shoot numbers of between 67 and 76%. Height growth of surviving trees was affected less by the treatment, with two of the three upland sites showing no decline and the third only a 26% decline. The blade plow treatment was ineffective at the Ferriday site which had poorly drained, fine textured soils. This may be due to the lack of moisture stress following blade plowing at this wet site. The seasonal trial for blade plowing in the spring at the Grambling site also demonstrated that lack of moisture stress immediately after blade plowing makes the treatment less effective. These findings indicate that blade plow use in ROW vegetation management should probably be limited to upland sites during the summer dry season to be effective.

Blade plowing did not reduce plant biodiversity on any of the treated sites compared to the mowed-only control. Consequently, the technique does appear to offer a tool to control unwanted tree species, while maintaining biodiversity of other plant species on ROWs.

The dot-grid herbicide technique using hexazinone and picloram had much more variable results than that of the blade plow treatment. The dot-grid technique was very effective at the Natchez site where the trees were larger and the soils were favorable. The treatment was ineffective at the Ferriday site where the high clay content of the soil may have tied up much of the Velpar herbicide, although premature mowing after treatment may also have been a factor. Treatment costs for the dot-grid technique as applied in this study were relatively high. Successful development of the technique in ROW vegetation management would require additional research on different herbicide trials, rate trials and dot-grid spacing studies on a variety of sites.

## ACKNOWLEDGEMENTS

This research was funded by Entergy Corporation. Special appreciation is extended to Mr. James R. (Randy) Williams who offered the insight and support that fostered this work.

## REFERENCES

Arner, D.H., J.D. Glover, D.R. Hartley, and J.C. Hunter. 1987. Vegetation changes on a right-of-way after repetitions of different management treatments. Proceedings of the Fourth Symposium on Environmental Concerns in Rights-of-Way Management. Indianapolis, Indiana. pp. 133–135.

Farrish, K.W., C.E. Rowell, and J.M. Dyer. 1993. Distribution of woody roots in transmission line ROWs in north Louisiana. Proceedings of the Fifth Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 90–91.

Glover, J.D. and D.H. Arner. 1993. The effect of glyphosate and prescribed burning on leguminous and woody plants on rights-of-way. Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 92–94.

Miller, J.H., B.R. Zutter, S.M. Zedaker, M.B. Edwards, and R.A. Newbold. 1995. Early plant succession in loblolly pine plantations as affected by vegetation management. Southern Journal of Applied Forestry, 19(3): 109–126.

Rowell, C.E., Farrish, K.W., and Dyer, J.M. 1993. Vegetation management alternatives on transmission line rights-of-ways in north-central Louisiana. Proceedings of the Fifth Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 176–179.

Shannon, C.E. and W. Weaver. 1949. The Mathematical theory of Communication. Univ. Illinois Press, Urbana, Illinois. 177 pp.

## *BIOGRAPHICAL SKETCHES*

***Charles E. Rowell***

*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

Charles E. Rowell is an Associate Professor of Forest Ecology and Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. in Political Science and M.S. in Forestry from Mississippi State University, and the Ph.D. in Forestry from the University of Kentucky.

***Kenneth W. Farrish***

*Arthur Temple College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962, USA*

Kenneth W. Farrish is an Associate Professor of Forest Soils in the Arthur Temple College of Forestry, Stephen F. Austin State University in Nacogdoches, Texas. Previously, he was a faculty member in the School of Forestry, Louisiana Tech University. He received his B.S. and M.S. degrees in Forestry from Michigan Technological University, and the Ph.D. from the University of Minnesota.

***James M. Dyer***

*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

James M. Dyer is a Professor of Wildlife Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. and M.S. degrees in Wildlife Management from Oklahoma State University, and the Ph.D. from Louisiana State University.

# Vegetation Management Alternatives on Electric Transmission Line Rows in North-Central Louisiana: Four Year Results

**Charles E. Rowell, Kenneth W. Farrish, and James M. Dyer**

Alternative vegetation management techniques were evaluated on two electric transmission rights-of-way (ROW) in north Louisiana over a four-year period. The objective of the work was to test techniques that select against trees, while allowing as many other plants to remain as possible. Comparisons were made between blade plowing and a mowed-only control, with follow-up treatments of burning, selective spot foliar herbicide application, and burning with selective spot foliar herbicide application. Blade plowing significantly reduced the number of tall tree stems compared to the mowed-only control. Spot herbicide application, especially in conjunction with blade plowing, was also very effective. Burning, however, did not reduce tall tree numbers. Generally, the follow-up treatments on the control plots (mowed only) had more trees with more stems of greater height than the same follow-up treatments on the blade plowed plots. Within site variability was extremely high at the Dubach site and analysis of variance indicated no significant difference among the follow-up treatments, although trends in reduction in mean tree numbers and size over the control were noted for the blade plow only, the blade plow with herbicide, and the blade plow with herbicide plus burning combinations. At both the Dubach and Simsboro sites, burning only, and blade plowing with burning were the least effective in reducing tree numbers, tree mean height, and cumulative tree height growth. Plant biodiversity was largely unaffected by all of the treatments, and the ratios of monocots to herbaceous dicots were also unaffected.

*Keywords:* Biodiversity, vegetation management, burning, selective spot foliar herbicide application, imazapyr, triclopyr, blade plow, woody root management, right-of-way

## INTRODUCTION

Managing vegetation on electric transmission ROWs in the southeastern United States requires frequent and costly treatments to control the rapid regrowth. Vigorous sprouting of tree species after conventional rotary mowing is the major vegetation management problem (Arner, Glover, Hartley, and Hunter 1978; Farrish, Rowell, and Dyer 1993). Tree stem numbers on ROWs in the region are commonly in the thousands per hectare, and height growth is rapid due to the long growing seasons (Rowell, Farrish, and Dyer 1993). Broadcast herbicide applications are effective at controlling the vegetation (Bramble and Byrnes 1976). However, increasing environmental concerns about maintaining plant species diversity on ROWs may require more selective control of tree species (Citizens for Environmental Protection 1981; Holewinski and Arner 1981; Huntly and Arner 1984). Consequently, vegetation management techniques are sought that will decrease the resprouting of tall tree species, while minimizing the impact on other plants.

In 1992, a research project was initiated to examine alternative vegetation management techniques that might be effective in controlling tree resprouting, while minimizing the impact on other plant species. Blade plowing was selected as a major treatment for this research because it had the potential to disrupt established woody root systems, while leaving shallow rooted, smaller plants intact. Follow-up treatments of burning, selective spot foliar herbicide application, and burning with selective spot foliar herbicide application were used, both with and without the blade plow. First-year result of this project were reported on at the previous symposium of this series (Rowell, Farrish, and Dyer 1993). This paper presents four-year results of the study.

## METHODS

Two study areas were selected in north-central Louisiana (near Dubach and Simsboro, LA) on 30 m (100 ft) wide, 150 kV electric transmission ROWs. The study areas were selected for similar soil and forest type characteristics that are representative of the region's upland mixed pine/hardwood forest ecotype.

The Dubach site was located on the Entergy Vienna–Bernice north–south 115 kV transmission line, northwest of Dubach, Louisiana. The soils of this site were classified as coarse-loamy, siliceous, thermic Typic Hapludults (Soil Survey Staff, 1975). The areas east and west of the Native Vegetation Management Study site were in varying levels of pine timber management, with three small areas (narrow drainage ways) dominated by hardwoods. Tree size, stand density and species composition varied along both sides of the ROW study area.

The Simsboro site was located on the Sterlington–Arcadia–Minden, east–west, 115 kV transmission line. The soils of this site were classified as fine-loamy, siliceous, thermic, Typic Hapludults (Soil Survey Staff, 1975). Three forest types were present adjacent to this study area. On the north side of the western end of the study area was a fully stocked, natural, pole-sized pine stand. Bottomland hardwoods dominated the central portion of the north side near a creek that crossed the ROW study area at its center. The east end of the north side of the study area was occupied by mixed pine/hardwoods, with small and large pole-sized pine and upland hardwoods. South of the ROW was a continuous, recently thinned, understocked mixed pine/hardwood forest.

The transmission line ROWs at the Dubach and Simsboro sites were over 30 years of age when the study was initiated. Both study areas were established in the second growing season of a two-year mowing cycle. The plant communities were well established, with herbaceous and woody plants fully occupying the sites. Evaluation of woody vegetation made prior to the treatment applications identified 17 tree species at the sites. Eleven of these species were determined to have a height growth potential that could eventually interfere with the transmission lines. The most common genera included pine (*Pinus*), elm (*Ulmus*), hickory (*Carya*), oak (*Quercus*), sumac (*Rhus*), and sweetgum (*Liquidumbar*).

The Dubach site ROW had a north–south orientation while the ROW at Simsboro ran east–west. Because of this, some of the Dubach plots in the ROW were shaded for almost six hours during the day. The plots at Simsboro were never shaded. Dubach had more variable forest plant communities adjacent to the ROW than that of the Simsboro site. The Dubach site also had a lower site quality for loblolly pine with a site index (height at 50 years) of 26.2 m (86 ft), versus 30.5 m (100 ft) at Simsboro. The Dubach site also had greater topographic relief (slopes) that affected micro-site radiation and soil moisture levels than the Simsboro site.

The vegetation on the study sites was cut during May 1992 with a rotary mower, the normal vegetation maintenance treatment for these ROWs. At each site, three replications of two major treatment plots [37 × 15.5 m (120 × 50 ft)] were established between the ROW center and the forest edge. One of each of the major treatment plot pairs in each replication was treated on June 15, 1992 with a 3 m (10 ft) wide blade plow (Savannah Forestry Equipment, Inc.) pulled by a Caterpillar D7 crawler tractor in an attempt to horizontally sever existing tree root systems 20–25 cm (8–10 inches) below the soil surface. Roots were also cut vertically with upstanding blades attached at 80 cm (2.5 ft) intervals on the upper surface of the blade plow. The remaining major treatment plots served as mowed-only controls for the blade plow treatment.

Each of the major treatment plots was then subdivided into four, equal sized, randomly assigned, follow-up treatment plots [9.2 × 15.5 m (30 × 50 ft)]. The follow-up treatments consisted of a summer selective spot application of low volume foliar herbicide, a late winter controlled burn (conducted in the winter because the vegetation would not carry fire in the summer), a summer selective spot application of low volume foliar herbicide with a late winter controlled burn, and a control (no follow-up treatment). Herbicide plots were treated with a mixture of 4% Garlon 3A (Triclopyr amine), 0.25% Arsenal (Imazapyr) and 1% LBF100 (surfactant), applied with a Philly Foam backpack sprayer in late July 1992. Only undesirable tree species were spot treated. Equipment, chemicals and operator were supplied by Asplundh, Inc. A winter burn was made on appropriate treatment plots in late February 1993.

Response data for this study was collected in the summers of 1993 and 1995. Tree sprouts and seedlings within a 2.3 m (7.5 ft) radius of each follow-up treatment plot center were identified by genus, measured for height (tallest stem of multiple stem clumps) and permanently tagged. Multiple stem clumps were counted as one individual tree for the tree number parameter. By dividing the number of total stems by the number of individual trees, the number of stems per tree was calculated. Other plants (woody and herbaceous) were quantified (number of species and occurrences) on a 1 $m^2$ sample plot located randomly in the treatment plots. Shannon–Weaver (1949) biodiversity indices were calculated for each of these sample plots.

During data analysis, plot values were converted to a per hectare basis. Cumulative tree height growth was calculated as the summation of the height of the dominant stems (Miller, Zutter, Zedaker, Edwards, and Newbold 1993). This value serves as an index of undesirable tree total growth. The replicated, randomized, nested design was analyzed using Analysis of Variance and Duncan's mean separation test.

## RESULTS AND DISCUSSION

### Site comparison

The Dubach site had much higher variability in the measured tree parameters, 32% fewer trees, and 34% fewer stems per tree than the Simsboro site during the 1993 measurements (Tables 1 and 2). The Dubach site also had 19% less mean tree height and 45% less cumulative tree height than the Simsboro site as well. These relative differences between the two sites were maintained in the 1995 measurement period.

The 1995 measurements indicated the control treatment at the Dubach and Simsboro sites had 1.6 and 20% respective increases in the number of trees since the 1993 measurements. The Dubach site had a 30% reduction in the number of stems per plant, while the Simsboro site had a 57% reduction (Tables 1 and 2). These reductions in stems per tree are probably due to self-thinning of multiple stems per individual.

### Blade plow treatment

Results at the two sites for treatment effects were generally similar. However, because of high variability and the relatively small sample size, the total number of trees remaining was not statistically different in 1993 between the control and the blade plow only treatment at Dubach. However, the trends in the data for the blade plow treatment at Dubach showed a 66% lower mean value in tree numbers (Table 1). The 1995 data indicated that the blade plow only treatment had a statistically lower (31%) value than the control.

The mean number of stems per tree actually increased significantly in the blade plow treatment over the control at Dubach in 1993, but mean tree height for

**Table 1. Tree sprout and seedling data for the treatment plots at the Dubach site**

| | Number of trees (×1000) ($h^{-1}$) | | Mean number of stems per plant | | Mean height (cm) | | Cumulative ht. growth (m × 1000) | |
|---|---|---|---|---|---|---|---|---|
| | 1993 | 1995 | 1993 | 1995 | 1993 | 1995 | 1993 | 1995 |
| Treatment — control | ns | * | ** | ns | ** | * | ns | * |
| Control | 15.6a | 15.3ab | 3.1bc | 2.2a | 50.3a | 108.7a | 7.4a | 6.9a |
| Herbicide | 10.9a | 17.5a | 1.4d | 1.2c | 32.3b | 84.5bc | 3.5a | 6.0ab |
| Burning | 10.9a | 11.4ab | 3.2ab | 1.9ab | 42.4ab | 81.0bc | 4.7a | 3.8ab |
| Herb/burning | 4.7a | 12.6ab | 2.3bc | 1.2c | 39.1ab | 78.2bc | 1.8a | 4.0ab |
| Treatment — blade plow | | | | | | | | |
| Control | 5.2a | 10.6ab | 3.8ab | 1.2c | 33.3b | 64.8c | 1.7a | 2.9ab |
| Herbicide | 2.7a | 3.0b | 3.5ab | 1.4bc | 33.5b | 100.1ab | 0.9a | 1.1b |
| Burning | 9.4a | 12.6ab | 3.3ab | 1.6abc | 42.4ab | 79.2bc | 4.0a | 4.0ab |
| Herb/burning | 7.7a | 7.9ab | 4.6a | 1.8abc | 32.0b | 74.2bc | 2.4a | 2.4ab |

Means in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test (ns = non-significant), (* = significant at $P = 0.05$), (** = significant at $P = 0.01$).

**Table 2. Tree sprout and seedling data for the treatment plots at the Simsboro site**

| | Number of trees (×1000) ($h^{-1}$) | | Mean number of stems per plant | | Mean height (cm) | | Cumulative ht. growth (m × 1000) | |
|---|---|---|---|---|---|---|---|---|
| | 1993 | 1995 | 1993 | 1995 | 1993 | 1995 | 1993 | 1995 |
| Treatment — control | ** | ** | ns | ns | ** | ns | ** | ** |
| Control | 21.9a | 27.9a | 4.7ab | 2.0c | 61.7abc | 148.8a | 13.5a | 17.8a |
| Herbicide | 15.3ab | 17.0ab | 4.4ab | 2.2bc | 53.8bc | 143.0ab | 7.7abc | 10.1ab |
| Burning | 15.3ab | 16.3b | 6.8a | 3.4a | 68.6a | 159.8a | 10.2ab | 10.9ab |
| Herb/burning | 12.4abc | 15.8b | 6.8a | 2.7abc | 55.9abc | 134.9ab | 6.8abc | 8.8ab |
| Treatment — blade plow | | | | | | | | |
| Control | 9.6 bc | 13.8b | 4.7ab | 2.3bc | 62.7ab | 144.5ab | 6.2bc | 8.1b |
| Herbicide | 4.5c | 10.4b | 3.5b | 1.7c | 47.5cd | 121.2b | 2.0c | 5.1b |
| Burning | 9.4bc | 12.1b | 4.9ab | 3.1ab | 53.1bc | 150.4a | 4.6bc | 7.5b |
| Herb/burning | 3.7c | 8.2b | 4.8ab | 2.4bc | 38.4d | 94.5c | 1.4c | 3.2b |

Means in a column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's mean range test (ns = non-significant, (* = significant at $P = 0.05$), (** = significant at $P = 0.01$).

the blade plow only treatment was statistically less than the control (Table 1). In 1995, this statistical difference in height remained, with the average total height on the control plots exceeding that of the blade plow treatment by 46%.

The cumulative tree height index value on the control and the blade plow treatments at the Dubach site was not statistically different in 1993, even though a 78% lower trend was noted for the blade plow treatment (Table 1). The cumulative height growth index between the control and the blade plow treatment was also not statistically different in the 1995 data, although the trend was 58% less than the control (Table 1).

At the Simsboro site, the total number of trees remaining on the blade plow treatment was statistically less than the control in 1993. The overall number of trees at this site did increase in 1995, but the statistical difference between the treatments remained, with the blade plow treatment still having 50% fewer trees. The mean number of stems per plant decreased between the 1993 and 1995 growing seasons, with no significant difference indicated between the blade plow treatment and the control.

No statistical difference was noted at Simsboro in the 1993 data for the cumulative height growth index. However, the 1995 data did show a significant difference, with the blade plow treatment having a 55% smaller cumulative height growth index than the control (Table 2).

### Follow-up treatments

Evaluation of the follow-up treatment combinations indicated that the blade plowing with spot foliar herbicide application, the blade plow with winter burning, and the blade plow with spot herbicide plus winter burning follow-up treatments all significantly reduced the number of trees and the cumulative tree height growth at Simsboro (Table 2). However, no significant differences among follow-up treatments were detected at the Dubach site, even though there was a large reduction in tree numbers and cumulative growth trends for the blade plowing with winter burning, and the blade plowing with spot foliar herbicide application plus winter burning follow-up treatments. These differences occurred in both the 1993 and 1995 data (Table 1). A statistical difference was noted at Dubach for blade plowing with spot herbicide in the 1995 data. The plot layout and the small number of treatment plots, along with high within site variability at Dubach may have been responsible for the low number of statistical differences.

Winter burning only and blade plowing with the winter burning follow-up treatment were the least effective in reducing the number of trees, mean heights and cumulative tree height growth index at the Dubach site (Table 1). The winter burning only, and blade plow with winter burning follow-up treatment were also the least effective at the Simsboro site (Table 2).

**Table 3. Herbaceous plant mean data for treatment plots on the Dubach Site**

| | Control | | | | Blade plow | | | |
|---|---|---|---|---|---|---|---|---|
| | Control (Sp/No) | Herbicide (Sp/No) | Burning, (Sp/No) | Herb/Burn (Sp/No) | Control (Sp/No) | Herbicide (Sp/No) | Burning (Sp/No) | Herb/Burn (Sp/No) |
| Monocots | 10/69 | 13/55 | 14/59 | 17/57 | 8/47 | 14/40 | 12/53 | 12/48 |
| Dicots | 13/93 | 15/212 | 19/96 | 10/115 | 19/81 | 11/26 | 29/62 | 24/74 |
| Trees | 7/18 | 14/36 | 11/56 | 9/32 | 8/37 | 8/35 | 8/31 | 11/44 |
| Shannon–Weaver diversity index | 1.32 | 1.10 | 1.56 | 1.22 | 1.62 | 1.51 | 1.63 | 1.74 |

Sp = The number of species found on three 1 $m^2$ plots.
No = The number of occurrences of all species found on three 1 $m^2$ plots.

**Table 4. Herbaceous plant mean data for treatment plots on the Simsboro Site**

| | Control | | | | Blade plow | | | |
|---|---|---|---|---|---|---|---|---|
| | Control (Sp/No) | Herbicide (Sp/No) | Burning, (Sp/No) | Herb/Burn (Sp/No) | Control (Sp/No) | Herbicide (Sp/No) | Burning (Sp/No) | Herb/Burn (Sp/No) |
| Monocots | 10/35 | 7/24 | 12/45 | 9/33 | 12/44 | 14/37 | 9/39 | 8/27 |
| Dicots | 20/61 | 11/32 | 20/50 | 14/43 | 17/50 | 17/30 | 19/51 | 20/43 |
| Trees | 10/30 | 9/26 | 10/23 | 11/24 | 9/23 | 9/14 | 10/16 | 6/07 |
| Shannon–Weaver diversity index | 1.61 | 1.47 | 1.59 | 1.56 | 1.49 | 1.62 | 1.66 | 1.53 |

Sp = The number of species found on three 1 $m^2$ plots.
No = The number of occurrences of all species found on three 1 $m^2$ plots.

### Treatment effects on plant biodiversity

Some of the treatments in this study that were aimed at reducing the tall tree species component of the vegetation communities on the ROWs were fairly successful. Because of the reduction in tree numbers due to the treatments, the woody plant component of the plant communities did decline. However, biodiversity of the remaining vegetation, as measured by the Shannon–Weaver diversity index, was not significantly impacted by any of the treatments (Tables 3 and 4). In addition, no discernible pattern existed in the relative numbers of herbaceous dicots and monocots on the treatment plots. Thus, blade plowing and some of the follow-up treatments appeared to achieve the stated goal of significantly reducing the tall tree species component of the vegetation community on the ROWs while maintaining maximum plant biodiversity.

## SUMMARY CONCLUSIONS

1. The study revealed that the upland vegetation communities in the ROWs were much less homogeneous than expected. High variability existed in plant community composition within sites. Considerable variation also existed between the study sites.
2. Blade plowing significantly reduced total tree numbers and the growth rates of surviving trees. The blade plow offers potential as a mechanical means of selectively controlling tree species on ROWs.
3. The follow-up treatments of selective spot foliar application of herbicide and spot foliar herbicide application plus winter burning further reduced tree survival and growth beyond blade plowing alone.
4. Blade plowing and the follow-up treatments did not change non-tree plant species biodiversity.
5. Winter burning by itself or in conjunction with blade plowing is not effective in reducing the tree sprouting problem, although it is immediately successful in the removal of above ground stems like cutting.

## ACKNOWLEDGEMENTS

This research was funded by Entergy Corporation. Special appreciation is extended to Mr. James R.(Randy) Williams who offered the insight and support that fostered this work.

## REFERENCES

Arner, D.H., J.D. Glover, D.R. Harley, and J.C. Hunter. 1987. Vegetation changes on a right-of-way after repetitions of different management treatments. Proceedings of the Fourth Symposium on Environmental Concerns in Rights-of-Way Management. Indianapolis, Indiana. pp. 133–135.

Bramble, W.C. and W.R. Byrnes. 1976. Development of a stable low cover on a utility right-of-way. Proceedings of the First Symposium on Environmental Concerns in Rights-of-Way Management. Mississippi State Univ., Mississippi State. pp. 167–176.

Citizens for Environmental Protection. 1981. Alternative methods of powerline right-of-way maintenance. Citizens for Environmental Protection. Charleston, West Virginia. Report no. DOE/R3/061122-T1-179. 3 pp.

Farrish, K.W., C.E. Rowell, and J.M. Dyer. 1993. Distribution of woody roots in transmission line ROWs in north Louisiana. Proceedings of the Fifth Symposium on Environmental Concerns in Rights-of-Way Management. Sept. 19–22. Montreal, Quebec. pp. 90–91.

Holewinski, D.E. and D.H. Arner. 1981. Environmental and economic aspects of contemporaneous electric transmission right-of-way management techniques. Proceedings of the Second Symposium on Environmental Concerns in Rights-of-Way Management. EPRI WS-78-141. pp. 1–14.

Huntly, J.C. and D.H. Arner. 1984. Rights-of-way maintenance to reduce cost and increase vegetation diversity and wildlife habitat — a demonstration. Proceedings of the Third Symposium on Environmental Concerns in Rights-of-Way Management. San Diego, California. pp. 342–351.

Miller, J.H., B.R. Zutter, S.M. Zedaker, M.B. Edwards, and R.A. Newbold. 1993. Early plant succession in loblolly pine plantations as affected by vegetation management. South. Journal of Applied Forestry, 19(3): 109–126.

Rowell, C.E., Farrish, K.W., and Dyer, J.M. 1993. Vegetation management alternatives on transmission line rights-of-way in north-central Louisiana. Proceedings of the Fifth Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 176–179.

Shannon, C.E., and W. Weaver. 1949. The Mathematical Theory of Communication. Univ. Illinois Press, Urbana, Illinois. 177 pp.

Soil Survey Staff. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA-SCS Agric. Handbook 436. U.S. Gov. Print. Office, Washington, DC.

## *BIOGRAPHICAL SKETCHES*

***Charles E. Rowell***

*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

Charles E. Rowell is an Associate Professor of Forest Ecology and Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. in Political Science and M.S. in Forestry from Mississippi State University, and the Ph.D. in Forestry from the University of Kentucky.

***Kenneth W. Farrish***

*Arthur Temple College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962, USA*

Kenneth W. Farrish is an Associate Professor of Forest Soils in the Arthur Temple College of Forestry, Stephen

F. Austin State University in Nacogdoches, Texas. Previously, he was a faculty member in the School of Forestry, Louisiana Tech University. He received his B.S. and M.S. degrees in Forestry from Michigan Technological University, and the Ph.D. from the University of Minnesota.

***James M. Dyer***
*School of Forestry, Louisiana Tech University, Ruston, LA, USA*

James M. Dyer is a Professor of Wildlife Management in the School of Forestry, Louisiana Tech University in Ruston, Louisiana. He received his B.S. and M.S. degrees in Wildlife Management from Oklahoma State University, and the Ph.D. from Louisiana State University.

# A Project Habitat® Initiative in Eastern New York State, February 1997

**Scott D. Shupe, Kenneth E. Finch, and Edward F. Neuhauser**

Ongoing Niagara Mohawk Power Corporation (NMPC) research evaluates right-of-way (ROW) selective vegetation management techniques to expand habitat for the host blue lupine plant of the endangered Karner blue butterfly (KBB), while retaining traditional ROW operations and maintenance techniques near Albany, New York. Routine broadcast herbicide applications in the 1960s and 1970s favored lupine by emulating a pioneer succession zone normally created by fire. Outside ROWs, this habitat continues to be lost to urbanization. A habitat preserve was formed in 1988, but only within the last five years have individual and group enhancement efforts become organized. In 1995, NMPC helped foster a coalition of these groups under the umbrella of Project Habitat®. This initiative favorably influenced the U.S. Fish and Wildlife Service to issue NMPC a research permit in lieu of an Endangered Species Act (ESA) 'incidental take' permit. Today's selective ROW vegetation management techniques favor shrub communities; we suspect this may be counterproductive, leading to the exclusion of nectar species. Hence, the research permit becomes a vehicle to enhance habitat, to preserve operations and maintenance options, and to reduce risk of ESA penalization.

*Keywords*: Project Habitat®, blue lupine, Karner blue butterfly, herbicides, Integrated Vegetation Management, plant succession, Endangered Species Act

## INTRODUCTION

The November 1996 trade journal *Electric Light and Power* carried an article recognizing 12 utilities for being first in the Nation to establish right-of-way (ROW) management programs designed to protect and enhance wildlife habitat under the new banner of *Project Habitat*®. But what is it? In 1995 American Cyanamid Company (maker of Arsenal® herbicide) sponsored a program in cooperation with the National Wild Turkey Federation, Buckmasters, and Quail Unlimited to help utilities improve habitats on their lands. Project Habitat® combines education, public relations, and grass roots occupation (literally) of lands traditionally managed for one purpose. Participants in Project Habitat® endeavor to manage lands for the original purpose (e.g., safe, reliable transmission of energy) while also making those parcels attractive to wildlife. The original projects focused on consumptive (game) species. This Karner blue butterfly (*Lycaeides melissa samuelis*) endeavor is the first partnership to promote a non-consumptive species, and enables Project Habitat® to bring on board organizations not normally aligned with hunting.

For years, to protect sensitive vegetation and ecosystems, regulators told us not to drive into wetlands. Today, many rare species in these wetlands are found only on the soil micro-topography perturbed by old-style construction methods. Similarly, high volume broadcast herbicide applications were discouraged, but today some rare plants thrive only where radical clearing and maintenance techniques were employed. Despite the 'green skills' our industry has acquired in the last 25 years, retrospect, contemporary research, and common sense suggest that in circumstances where the goal is micro-habitat manipulation, selective and invasive techniques may be more beneficial than preservation. Elements of the older methods may be superior when the goal is promotion of endangered species habitat.

## BIODIVERSITY AND INTEGRATED VEGETATION MANAGEMENT

Niagara Mohawk Power Corporation (NMPC) recognizes that many of today's politically correct buzzwords are simply old ideas repackaged by science. Aldo Leopold (1949) postulated that *"the first rule of intelligent tinkering is to save all the parts"*. More recently, Jack Ward Thomas commented that the Endangered Species Act (ESA) should be recast to emphasize ecosystem protection. He stated that *"The true intent and challenge for managers is to preserve the ecosystem upon which species depend, not the individual species."* (Greenwire 11/13/96). In managing its ROWs, NMPC has found that these principles of biodiversity can be applied in local habitat circumstances for ecosystem protection, virtually at no-cost, while guaranteeing line integrity, and winning points for stewardship. Its fundamental strategy may employ Integrated Vegetation Management (IVM).

Integrated Pest Management (IPM) is a strategy employing multiple methods of pest control, rather than reliance on one procedure. IVM is the component of IPM which balances the use of cultural, ecological, mechanical, and chemical procedures for controlling undesirable vegetation (McLoughlin 1996). Ideally, IVM mixes alternative control methods to minimize use of chemical and mechanical control methods over the long-term, and relies extensively on natural or induced ecological processes to achieve stands of vegetation that retard other species capable of compromising overhead line integrity (EPRI 1995). NMPC has evolved over the last twenty years a ROW management technique that fosters a desirable, low-growing plant community using IVM (Finch and Shupe 1997). However, prior techniques on some ROWs recreated the habitat for an endangered butterfly. IVM now plays an important role in sustaining that habitat.

## ROW CLEARING HISTORY

Bramble and Brynes (1983) working in Pennsylvania helped give rise to IVM. On a three-mile segment of ROW first cleared in 1951–2, and using early herbicides, they documented a progressive conversion of the forest ecosystem into a shrub and grass/forb community that attracted wildlife. At the same time Rachael Carson (1962) began enlightening the world as to the dangers of chemicals. In the decades since, industry, applied scientists, and fledgling governmental and non-government organizations have been seeking to balance each others' perceived roles as stewards of the environment. Much of the debate has been if and how pesticides should be used.

By the late 1970s, NMPC's ROW management procedures and data were being scrutinized by the New York State (NYS) Public Service Commission (PSC) and the NYS Department of Environmental Conservation (NYSDEC). Broadcast foliar treatments seemed to have set back plant succession to its earliest stages. But, NYSDEC's Endangered Species Unit (ESU) was concerned that NMPC's methods would adversely affect one of the pioneer plants — the native blue lupine (*Lupinus perennis*).

Sensitized to changing public values, in 1980 the PSC ordered the NYS investor-owned utilities to develop long-range ROW management plans and strategies which included the precepts of selective, integrated management. These precepts included preservation of 'desirable' species — why spray something that will not grow into overhead lines? But as suburbs expanded into transmission lines, NMPC found it increasingly difficult to foliar spray at all.

As NMPC converted to a selective vegetation management scheme to save money and chemical, and to favor low growing shrub communities, the ESU noted that conditions for lupine seemed to have deteriorated. The ESU wanted a more invasive management technique, but was undersold with IVM at this time of growing anti-chemical sentiment. NMPC then tried mowing, with a dormant season cut-stubble herbicide application. Interestingly, NMPC found the regulatory agencies quite receptive, especially the ESU.

The Karner blue butterfly (*Lycaeides melissa samuelis*), living on NMPC ROWs, had captured the public's attention in the state's capital region (Sigurdsson 1992; Fair 1993). It was listed as a NYS endangered species in 1977; lupine was its host plant.

## LUPINE AND KARNER BLUE BUTTERFLY LIFE HISTORY

Karner blue butterfly (KBB) habitat is a dry, periglacial, pitch pine-oak-sand belt complex spanning four counties in eastern NYS and New Hampshire on which the butterfly was first described. KBB also live in the oak savannah of Ontario, Minnesota, Indiana, Wisconsin, Ohio and Michigan. The insect's life span is about five days. It has two, 2-week flight periods, one in early June, another in late July. The larval butterfly feeds on lupine foliage. The adult selectively feeds on blue lupine and other nectar species, then lays its eggs in the lower whorls of the lupine plant, about 8 inches above the soil (Packer 1990).

Lupine first blooms in late May and blossoms fall by early August. Stands of 500 or more plants each are required to support shifting clusters (metapopulations) of KBB. In the old days, lupine seeds were carried into soils where intense summer wild fires had consumed the duff. Sandy soils repeatedly purged of organic layers made good seed beds. There the plants had little competition and lots of light. Smallidge (1992) provides strong evidence that an intense light level is an important determinant for the success of lupine. Seeds falling into oak leaf litter, which is rich in tannin and slow to decay, never reach the soil to germinate. If they do, plants are shaded out by the taller, woody overstory.

Schweitzer (1989) and other lepidopterists believe that fire must be used to recreate habitat suitable for lupine. Native Americans used fire for vegetation management — their technique for the biodiversity vision of that era. But wild fires are no longer acceptable in a countryside fragmented by domestic and commercial enterprises, and bound by a Clean Air Act, so fire for ROW management has been abandoned.

Schweitzer theorizes shifting clusters of KBB recolonized post-wildfire habitats as lupine established large plant stands across the sand barrens. No areas were permanently depopulated until fires were controlled and habitat was so fragmented that metapopulations were too far apart to maintain the species. This progression is somewhat supported by the documentation that New York forests, only 25% of its land in 1880, cover 62% of the state today (USDA 1993).

Previously reticent for line safety and perceptions of adverse publicity, NMPC now is now to allowing controlled burning experiments on its lines and on protected private and public parcels next to its ROWs. The Albany Pine Bush Preserve Commission has both NYSDEC-ESU and public support for its fire trials.

## THE NEW PARTNERSHIP

### Recognition

at about the time NMPC was entering its third cycle of IVM treatments, it suggested that there are other means to emulate the result of fire. ESU enlisted NMPC's help, since the utility had been cooperating with the agency to schedule vegetation maintenance work around KBB flight periods. The ESU also inferred that initial broadcast herbicide treatments had unintentional but positive effects on lupine populations, and had enhanced dispersal corridors connecting spatially discrete KBB populations (Smallidge 1992). ESU informed NMPC that, despite its efforts and capital expenditure, the greatest numbers of KBB metapopulations were on ROWs and at the Saratoga County Airport, which was mowed twice a year.

NYSDEC-ESU reconsidered the effects of mowers and herbicides. Likewise, the mowing at the airport also probably emulated fire's role in setting back plant succession. Additionally, the vehicular disturbance of the ground by mowers may have groomed a seedbed. Swengel (1996) believes that mowing emulates grazing by a host of mammals no longer present, but which formerly held the ecosystem in balance; he disapproves of fire as a management technique. Borth (1996) also questions controlled burns. Although potentially harmful to extant butterflies, fires may be used to prepare seed beds for cultivation of lupine and subsequent occupation by butterflies.

NMPC and NYSDEC-ESU were now theorizing that, for a successful lupine/KBB microsystem, the PSC's mandated desirable shrub order may be counterproductive, causing deterioration of plant succession conditions favoring lupine. It was at this time a decade of rather unstructured cooperation for the species began to crystallize a sizeable group of interested parties heretofore cautious of one another.

### Project Habitat® as the catalyst

Ideally, one will find a task easier and more complete if others share. So together, the regulators, those who disliked the concept of herbicides, chemical advocates, and those who wanted to use NMPC ROWs for their purposes (purposes not always viewed as compatible with safe transmission of energy) paid attention to each others' agendas. Project Habitat®'s genesis in 1995 was a timely catalyst.

The partners in NYS's first Project Habitat® endeavor are: the NYSDEC, the U.S. Fish and Wildlife Service, the Albany Pine Bush Preserve Commission, The Nature Conservancy, American Cyanamid Company, and NMPC.

For several years after extant lupine and KBB metapopulations had been identified on our ROWs, NYSDEC's Endangered Species Unit wanted NMPC to post signs at each site; NMPC was reluctant.

- Vandalism and pilferage were problems in this urban area.
- Why put up a sign to advertise an endangered species?
- What would the signs say, and who would pay for and erect them?

NMPC rethought use of signs. A sign was designed and endorsed as a vital communication tool, one bringing an important message to all field forces working on our ROWs. Project Habitat® signs, replete with text written by NYSDEC and displaying the logos of all participants, now seemed appropriate. Its text cautions those entering the ROW that sensitive habitat is present, and that before starting any work, they should first call one of two phone numbers for advice on how to proceed.

NMPC printed and paid for the signs, and NYSDEC agreed to maintain them. Delivering a few signs to each of the participants for publicity, signs were then installed at the perimeters of 73 distinct lupine plots. After six months, only a few have been pilfered. This $8 plastic sign crystallized a pact between previously suspect parties. The public recognition and publicity has been overwhelmingly favorable, even from employees we suspected would dismiss the significance of the undertaking. One of the cornerstones of the discussions during 1995's partnership development was research completed for NMPC three years earlier.

## RIGHT-OF-WAY MANAGEMENT AND RESEARCH

Since 1980, NMPC knew it had lupine and KBB clusters on its ROWs, but neither it nor NYSDEC had inventoried them. In 1992, NMPC commissioned the State University of New York College of Environmental Science and Forestry (ESF) to inventory over 640 km (400 miles) of ROW (≥ 34.5 kV). Using GPS techniques, 71 lupine patches and 15 KBB metapopulations were located. More have since been found. As expected, the initial study demonstrated the lack of information available on the impact of vegetation management on the butterfly and its habitat, specifically the blue lupine plant. But it concluded that vegetation management techniques to eliminate scrub oak, locust, pine, aspen and other species which grow into conductor zones benefitted lupine by eliminating shade. Entities destined to become partners in Project Habitat® began to recognize that line maintenance vehicles and herbicides played a significant role in creating and sustaining lupine seedbeds. Although the Albany Pine Bush Preserve Commission (1993) had considered discouraging herbicide usage, its staff was now soliciting NMPC's advice on appropriate mixtures to control woody vegetation on Preserve lands.

So, in 1995 the ESF contract was modified, additional sites were located, and 28 ROW sites (absent extant KBB) were selected for test treatment plots. On these sites the structure and composition of trees, shrubs, and herbs is recorded. Against control sites, six treatments are imposed and will be monitored for eight years:

- modified high volume broadcast herbicide application (foliar),
- low volume selective foliar application (backpack),
- cut and stump treatment with herbicide,
- cut with no stump treatment,
- mowing on a regular cycle (2–3 years), and
- annual mowing.

The first four treatments are traditional NMPC techniques to manage woody stems on electric ROW's, the next two are used on gas lines, and the last is for "Others" who may be able to adopt plots for lupine cultivation elsewhere off the ROWs.

NMPC's research strategy for the ROW-lupine-butterfly association developed along three paths, (1) validate methods which provide cost effective means to manage the ROWs, including continued use of herbicides; (2) improve methods to expand/propagate lupine populations, including fostering partnerships which integrate multiple uses of our ROWs in the Albany Pine Bush Preserve; and (3) continue the ESF R&D project to study effects of ROW vegetation management on blue lupine, an effort which lends itself to (1) and (2). The main goal of the research is to determine which of the available IVM strategies and techniques can be optimized to fulfill NMPC's goals of cost-effective, reliable ROW vegetation management while providing optimal conditions for the blue lupine and other nectar plants.

## THE APPLIED VALUE OF RESEARCH AND PARTNERSHIP

### Listing

In September 1991, the USFWS notified NMPC that the KBB was proposed for listing, and that it wanted our help in conservation and recovery activities for this species. We were then admonished that the species had already been listed as endangered by the NYSDEC, and was therefore protected from taking, including adults, larvae, and eggs. Moreover, alteration of essential habitat was subject to compliance with NYS law. Although NMPC had cooperated for eleven years with the agencies' interest in this butterfly on our ROW's, we were strictly liable. The butterfly was listed, with no critical habitat, on 14 December 1992 (FR).

### Court case

In a 6–3 ruling, the 1995 Supreme Court decided that the government can prohibit the destruction of habitat on private property. In *Babbitt vs. Sweet Home of Communities For a Greater Oregon (No. 94-859)* the court upheld the USFWS's interpretation of 'take' — "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" — to include modification of habitat as synonymous with "harm". Interior Secretary Babbitt defined 'harm' to include "significant habitat modification or degradation that actually kills or injures wildlife". The Court has since refused to consider arguments that Federal Law requires proof of concrete harm to species before the government can impose restrictions on private property. While most utilities take easements, Niagara Mohawk owns most of its higher voltage ROWs, so the case was critical.

### 'Catch 22'

NMPC was considering asking to grow more butterflies so it could increase our probability of killing them in violation of the law! Why should it cooperate? NMPC is risk-averse and does not wish to be sullied by any such claim or the costs of refuting an allegation.

Furthermore, by orders of the NYS Public Service Commission, NMPC was obligated to prescribe a maintenance strategy on its electric rights-of-way that clearly is habitat alteration. IVM inexorably relies on the application of registered herbicides. NMPC's problem was to comply with apparently conflicting state and federal mandates. How?

The key was to demonstrate that the habitat "modification" was not habitat "destruction". The challenge was to prove this in a cost-effective, non-adversarial manner. NMPC's solution was the integration of some research and development, communication, professional cooperation, and common sense. So far, all parties seem to be winners.

## ENDANGERED SPECIES ACT FILING OPTIONS

Upon deciding that ESA compliance was a wise business move, NMPC pondered how to apply for a permit. Its initial perspective was that during the course of maintaining the lines or treating vegetation, butterflies in flight would be harmed, hence NMPC would be guilty of an "incidental take".

Now 50 CFR § 10 and § 13 are deceptively simple; you send $25 attached to a one page permit application form. You support the application with a simple habitat conservation plan (HCP) to monitor the species you are "taking".

Scanning the Wisconsin HCP's dozens of flow charts, pages of participant lists and testimony, references to antitrust pilot studies, modeling, inventories and mapping, GIS requirements, homework assignments, alternative land management plan proposals, annual reports, herbicide research, et cetera, it became evident that an HCP was anything but "user friendly".

### USFWS role

NMPC wrote a relatively short plan and asked for a maintenance "incidental take" permit, in perpetuity. Surprising NMPC, the Service thought NMPC could qualify for a § 17 scientific permit, rather than applying for an "incidental take" which required an HCP. Moreover, NYSDEC agreed, but wanted to take the lead and require NMPC to get a permit from it, instead. USFWS, however, said that NYSDEC had not yet formulated a complete state recovery plan for KBB, so NMPC's Federal application would meanwhile take precedence.

NMPC described Project Habitat®. The USFWS recognized this approach, and following a few months of informal exchanges, expedited NMPC's filing for an eight-year research program permit under the ESA. The permit not only recognized the importance of herbicides, but it ultimately embraced NMPC's unfettered ROW management on almost 1,000 miles of gas and electric ROW's. A commitment to research generated a win-win protection and enhancement scenario for butterflies and nectar species without the tribulations of an expensive HCP. USFWS was happy; it sensed an amicable success in its mission. It requested (and got) approval to use NMPC's photos of KBB in its web page and ESA brochure. NYSDEC secured its desired signs, and access to our powerlines and reports.

### Permit obligations

Most importantly, our negotiations resulted in an acceptable permit. NMPC will inventory its gas lines for lupine and KBB, and monitor any changes on the electric lines. NYSDEC agreed to conduct the monitoring program. Specific conditions of the permit include:

- Limit the height of our mowers to 20.3 cm (8 inches). (NMPC does not normally use herbicides on gas lines, which are mowed every three years.)
- Herbicide treatments will be every 7–8 years, mostly by backpack or low pressure hydraulic hose rigs stationed outside lupine patches.
- Known KBB sites will be avoided from 1 April through 31 August. NMPC wanted access by 1 August, but since only about 15 occupied spans are known, it will have to bypass only three or four sites each year on an eight-year cycle. Crew remobilization costs to avoid KBB will be negligible.
- NMPC agreed not to pile brush debris near lupine. Rabbits, deer, and woodchucks eat lupine, so they are deprived of shelter.
- Signs are to be posted to alert crews to sensitive habitat. A six-minute videotape carries this message to all regional employees.
- Finally, NMPC submits an annual summary each March 31 reporting any takings, results of the R&D, and announcing the next year's maintenance schedule.

By the end of 2003's treatment cycles and the ESF R&D project, USFWS expects that enough new lupine will have emerged, and more KBB will be seen, that the permit can be renewed with more favorable conditions. NMPC hopes to relax the 31 August date to enable it to reduce crew jumps. This would mean that a few lupine plants will be expendable *because* our IVM techniques and Project Habitat® will have significantly increased overall populations.

## RELATED OPPORTUNITIES

Successfully orchestrating a partnership will probably result in new parties surfacing with additional resources or experience. Soon after signs were posted on ROWs, NMPC was contacted by the local Boy Scout Camp Director. One protected plot was on a line that crossed Camp Saratoga. NMPC learned that Scouts had an active program to cultivate blue lupine, and were attaining a success level not shared by others studying or practicing recovery techniques. Knowing that the Scout's low cost methods of preparing seeds, preparing seed beds, protecting plants, and expanding/dispersing root propagules (emulating the effects of wild fire in yet another way) would be of interest to the Project Habitat partners, NMPC 'cross pollinated' discussions. Consequently, The Nature Conservancy is researching the property, and the USFWS supplied the camp with bulldozer rentals to prepare additional ground, and purchased deer fencing to reduce grazing.

NMPC has also learned that interest in pioneer nectar species is shared by a variety of urban horticultural groups, agribusiness, and agencies. Collectively they have noted a reduction in apiary and wild bee numbers. The increasing reversion of NYS forest land and growing number of acres in residential lawns has reduced the plant diversity, reducing habitat for pollinators. While disease and parasitism in wild bee populations are still a concern, NMPC's ROW maintenance program to promote and sustain pioneer species will also help feed and disperse pollinating species along the 1000 miles of ROW in these four counties.

The Project Habitat initiative has piqued the interest of Pheasants Forever, the Ruffed Grouse Society, and the NYS Conservation Council. NMPC will be studying opportunities for enhancement of habitat for new candidate species. As NYS forests mature, the shrub community needed for grouse and migratory woodcock, the shallow wetlands needed for migratory shorebirds, and agricultural borders providing cover for pheasants is lost. Project Habitat may be the vehicle to involve more citizens and to publicize positive programs of utilities and industries under fire as deregulation comes of age.

Finally, as more ROWs are recognized as repositories of sensitive habitats isolated by development or land use changes on adjacent lands, an opportunity may present itself to explore the concept of 'habitat banking' of ROW's and utility properties. This concept is one to evaluate for the next ROW Management Symposium.

## SUMMARY

Niagara Mohawk's participation in its first Project Habitat endeavor suggests that others seeking to integrate wildlife habitat enhancements (especially for endangered species) with land management programs should:

- Learn the biology and ecology of your target species,
- Learn how its habitat evolved on your parcel,
- Learn the agendas and needs of your opponents and supporters,
- Orchestrate a partnership with both,
- Educate them of your needs and speak frankly of your reservations,
- Scrutinize the legislation and Code of Federal Regulations,
- Be flexible,
- Contract for, and leverage appropriate research,
- Encourage others to publicize the partnership and its goals,
- Dedicate money for a long-term habitat conversion process, and
- Employ the traditional Boy Scout training message —KISMIF (keep it simple, make it fun)!

Can utilities learn this is a competitive environment?

## REFERENCES


Albany Pine Bush Preserve Commission. 1993. Management Plan and Environmental Impact Statement for the Albany Pine Bush. 152 pp.

Borth, R. 1996. Response to Karner Blue Habitat Conservation Plan homework. Wisconsin Electric Company. 29 pp.

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

Carson, R.L. 1962. Silent Spring. Houghton Mifflin, Boston. 368 pp.

Editor. 1996. Utilities receive honors for wildlife conservation efforts. Electric Light and Power. p. 11.

EPRI (Electric Power Research Institute). 1995. Vegetation management by electric utilities: use of herbicides and other methods. Technical Report 104935. Pleasant Hill, California. 32 pp.

Fair, T.R. 1993. Utility helps protect a rare and endangered butterfly. Electric Light and Power. p. 20.

FR (Federal Register). December 1992. Final Rule listing Karner blue butterfly, 57(240): 59236–244.

Greenwire. An on-line Internet environmental news service.

Leopold, A. 1949. A Sand County Almanac. Oxford Press, New York. 226 pp.

McLoughlin, K.T. 1996. Application of integrated pest management to electric utility rights-of-way vegetation management in New York State. New York Power Pool Position Paper. Altamont, New York. 11 pp.

Packer, L. 1990. The status of two butterflies, Karner blue (*Lycaeides melissa samuelis*) and frosted elfin (*Incisalia irus*), restricted to oak savannah in Ontario. In: Conserving Carolinian Canada. G.M. Allen, P.F.J. Eagles, and S.D. Price, eds. University of Waterloo Press. pp. 253–271.

Sigurdsson, F. 1992. Save the Karner blue! Backpacker. p. 9.

Schweitzer, D. 1989. Fact sheet for the Karner blue butterfly with special reference to New York. The Nature Conservancy. NY Field Office, Albany, New York. 7 pp.

Smallidge, P.J., D.J. Leopold, and C.M. Allen. 1992. 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.

Swengel, S. 1996. Personal letter to Ed Neuhauser. Entomologic researcher. Baraboo, Wisconsin. 31 January.

USDA-Forest Service. 1995. The Empire State's Forests — Trends in a robust resource. NE-INF-126-95. Radnor, PA. 4 pp.


## *BIOGRAPHICAL SKETCHES*


***Scott D. Shupe***

*Niagara Mohawk Power Corporation, 300 Erie Blvd West, A-2, Syracuse, NY 13202, USA*


Scott D. Shupe, Environmental Analyst at Niagara Mohawk, holds a B.S. in Biology and a M.S. in Water Resource Management from SUNY College of Environmental Science and Forestry, and a M.S. in Science Management from the University of Alaska-Anchorage. In consulting, government, and industry, his career has spanned the planning-construction-operations spectrum, including all elements of high-voltage power line construction contract management, small hydropower and navigation planning. He currently supports non-nuclear generation, gas, and electric system operating and licensing groups.

*Kenneth E. Finch*
*Niagara Mohawk Power Corporation, 300 Erie Blvd West, A-2, Syracuse, NY 13202, USA*

Kenneth E. Finch, Managing System Forester, holds a AS from Paul Smith's College, and a B.S. in Resource Management from SUNY College of Environmental Science and Forestry. Following the Army and a tour with Asplundh Tree Company, he joined NMPC as a Forestry Foreman and has risen through the ranks to become the Company's top forestry professional.

*Edward F. Neuhauser, PhD*
*Niagara Mohawk Power Corporation, 300 Erie Blvd West, A-2, Syracuse, NY 13202, USA*

Edward F. Neuhauser, Senior Research Specialist, holds a B.S. and Ph.D. in Soil Biology from SUNY College of Environmental Science and Forestry. He is responsible for a variety of renewable and energy storage research programs, as well as environmental, water resource, hazardous material, remediation, and safety research adventures at Niagara Mohawk. He participates in task forces and review committees for the Electric Power Research Institute, Gas Research Institute, and Edison Electric Institute.

# Part III
# Roads

# Vegetation Management: Trends and Training in Transportation

**Bonnie L. Harper-Lore**

As land managers, highway agencies make decisions for over six million hectares of land. Because all rights-of-way managers (i.e., pipeline, electrical power, railroad, and highway) have the responsibility of managing corridors in a time of dwindling budgets, it is wise to share what we have learned with one another. They have two educational needs in common: (1) internal training in order to use the best known practices; and (2) public awareness in order to gain public support for our decisions. This paper intends to explain the past trends in vegetation management that led to the current trend in integrated roadside vegetation management (IRVM). This paper addresses the resulting changes in vegetation managers' attitudes and the public's expectations. A video[1] is introduced which communicates current trends to internal staff, as well as the public. The video tool is a cost-effective way to train staff and the public about the 1990s right-of-way management approach.

*Keywords*: Video, integrated roadside vegetation management (IRVM), training, public awareness, ecologic-economic approach, Executive Memorandum on landscaping

## BACKGROUND — VEGETATION MANAGEMENT TRENDS

In the 1930s, roadside development programs were established in State Highway Agencies across the country. At that time highways acknowledged that their corridors accommodated more than road-building. Landscaping and maintenance of the remaining real estate was given attention in an effort "to improve the appearance and usefulness of roadsides". The unofficial management policy of the roadside development programs is reflected in the title of Bennett's (1936) book, "Roadsides, the Front Yard of the Nation". The front yard look was interpreted as that well-kempt, manicured front lawn of each of our homes. Within State Highway Agencies, maintenance crews took pride in that level of care. The public began to expect it.

In the 1950s, the advent of herbicides to control vegetation helped make that level of care possible, but it was also costly Mowing and spraying together became the method that aimed for that front yard ideal. This "agricultural approach" to vegetation was costly in terms of man hours, and ultimately to the environment. Herbicides affected water quality plus remnant plant communities disappeared. Vegetation management crews worked effectively with the tools available to them. The public demanded that level of care.

In the 1970s, the "energy crunch" hit vegetation managers with reduced fuel budgets and limited the agricultural approach. In search of alternatives, many explored the idea of working with natural processes, or an "ecological approach". In effect, economics had given birth to an ecological solution. Many vegetation managers resisted the change to reduced mowing, spot spraying, and prescribed burn alternatives. The public was confused by the changes they saw and many requested the front yard look.

In the 1990s, land managers across the country needed both increased funding to explore ecology-based solutions, and improved support from the public. In an attempt to do both with an ecologic/economic approach, the Clinton Administration released an Executive Memorandum (EM) promoting "environmentally and economically beneficial landscaping"; the memorandum

1 This combination internal training/public awareness video is available from the author at no cost as long as the supply lasts.

recommended the "use of environmentally beneficial landscaping techniques, including increased use of native species and reduced use of water and chemicals, at federal facilities and federally-funded projects, where appropriate." For State Highway Agencies, the EM was supportive of the emerging ecologic/economic approach in need of support. More roadside managers were able to move away from the front yard look towards a natural aesthetic where appropriate. The traveling public continued to need an explanation.

## A VIDEO TRAINING AND AWARENESS SOLUTION: TWO AUDIENCES WITH ONE TEACHING TOOL

In 1997, the Federal Highway Administration produced a video aimed at explaining the trend away from the "front yard of the nation" management for State Highway staffs and the public. Video segments from highway agencies across the country were compiled to demonstrate visually what the ecologic/economic approach looks like and how it works. Segments were able to make the following statements:

*Maryland encourages public partnerships*
Working with volunteers to do "more with less" is an economic necessity. Volunteers can help with ecological goals.

*South Carolina shows signs of creative funding*
Funding from license plate revenues supplements minimal roadside budgets. Creative public awareness efforts build support.

*Florida uses native plants and xeriscaping principles*
Granting projects that include ecological components also rewards beautification efforts.

*Texas promotes its natural heritage*
Restoring native vegetation results in increased tourism.

*Minnesota reduces herbicide use*
Using prescribed burns as a management tool serves as an alternative to herbicide use in an integrated management approach.

*North Dakota goes wild*
Encouraging private/public partnerships builds support for native restoration projects.

*Oregon protects rare and endangered species*
Signing rare and endangered species aids vegetation managers in protecting Oregon's ecosystems.

*California acts as a land steward*
Establishing statewide environmental policy encourages vegetation managers to respect ecologically-based vegetation management.

## CONCLUSIONS

### Support for vegetation managers and roadside environment

These key statements demonstrated the ingredients of the ecologic/economic approach encouraged by the Executive Memorandum. The video segments underscored the importance of the partnership of highway vegetation managers and the highway users in "Taking Care of Roadsides". Highway users are able to: volunteer to pick up litter, plant trees and wildflowers, and support roadside maintenance efforts. Further support to vegetation management was given by FHWA Deputy Administrator, Jane Garvey, with these words:

> "On behalf of both Rodney, and myself, let me offer a particular note of congratulations to those of you who have worked so hard in programs and partnerships that protect and enhance the nation's roadside environment."

This training/public awareness piece will be used across the nation to underscore that vegetation managers can no longer afford to care for roadsides as if roadsides are our front yards. Rather managers can take pride in an ecologic–economic approach (IRVM) that demonstrates stewardship towards the millions of hectares that they manage. In turn, with increased public awareness, the public will no longer expect the level of care initiated in the 1930s, but be willing to accept an ecologic/economic approach that demonstrates a level of care which is environmentally friendly for well into the future.

## ACKNOWLEDGEMENTS

The video was produced through the patience of Gary Pund and his Caltrans Video Unit. Music was provided by Keep America Beautiful, Inc., a non-profit, public education organization dedicated to improving waste handling practices in communities nationwide. Video segments were offered by State Highway Agencies including: California, Florida, Maryland, Minnesota, North Dakota, Oregon, South Carolina, Texas and Wisconsin. Photographs were shared by Arkansas, California, Iowa, Missouri, Nebraska, Oklahoma, Oregon, Puerto Rico, South Dakota, Utah, Virginia, and Wisconsin. Jane Garvey footage was produced and provided by the FHWA Photography Services.

## REFERENCES

Bennett, J.M. 1936. Roadsides, the Front Yard of the Nation. The Stratford Company, Boston, Massachusetts.

Foote, L E. 1976. Comparisons of agronomic and ecological approaches to roadside management. Notes of the Summer TRB Maintenance Committee Meeting.

Harper, B.L. 1988. Return of the natives to Minnesota roadsides. Transportation Research Record, No. 1189: 78–80.

Harper-Lore, B,L. 1996. Is hands off management possible? Greener Roadsides, Vol. 3 No. 3. FHWA, Washington, D.C.

Harrington, J.A. 1991. Survey of landscape use of native vegetation on Midwestern highway rights-of-way. Transportation Research Record, No. 1326: 19–30.

Haywood, B. 1992. Haywood approach to integrated roadside vegetation management. Roader's Digest, 4(1), University of Northern Iowa, Cedar Falls.

Leopold, A. 1949. A Sand County Almanac. Oxford University Press, Inc.

Office of the Federal Environmental Executive. 1995. Guidance for Presidential Memorandum on environmentally and economically beneficial landscape practices. Federal Register, Vol. 60, No. 154: 40837–40841.

Walvatne, P., ed. 1997. How to develop and implement an integrated roadside vegetation management program. National Roadside Vegetation Management Association, Newark, Delaware.

## *BIOGRAPHICAL SKETCH*

***Bonnie L. Harper-Lore***

*Roadside Vegetation Coordinator, Federal Highway Administration (FHWA), 400 Seventh Street SW, Washington D.C. 20590, USA*

Bonnie Harper-Lore has designed with native plants in the private and public sectors since 1976; taught ecological principles of design at the University of Minnesota for nine years; worked with roadside vegetation in transportation corridors since 1986; and edited a quarterly FHWA newsletter, *Greener Roadsides*, since 1993. She currently serves as the FHWA vegetation resource for all 50 State Highway Agencies, as well as serving on the Federal Interagency Committee on Weeds and the Federal Native Plant Initiative.

# Part IV
# Project Planning

# Designing Groundwater Monitoring Programs for Rights-Of-Way Facilities

**Boyd Allen III**

A challenging hurdle for rights-of-way and associated facilities is assessing potential impacts on groundwater resources. Measuring these impacts is both a scientific and public perception issue. Some impacts may not be quantified until several years after construction or initial operations. The general public's basic understanding of groundwater is often limited; their concerns focus on impacts on something they physically cannot see. Too often, industry monitoring programs become reactive responses to concerns raised by the public in the review and comment period. A proactive monitoring program presented in the initial planning stages of a project can reduce public skepticism and defuse fears about impacts on private wells, public water supplies and other groundwater resources. This paper considers several limited monitoring program approaches potentially applicable to linear facilities and stations (i.e., pipelines, gas compressor stations, oil pumping stations, etc.) that measure potential impacts on groundwater resources stemming from blasting, construction dewatering and wastewater discharge. These programs emphasize economical hydrogeological monitoring approaches and screening and indicator compound oriented chemical analyses. Such programs can minimize impacts on project costs while still providing timely technical information to evaluate impacts on groundwater resources.

*Keywords:* Groundwater, monitoring, construction, right-of-way, environmental impact, linear facilities, screening parameters

## INTRODUCTION

A challenging hurdle for rights-of-way and associated facilities is assessing potential impacts on groundwater resources. Measuring these impacts is both a scientific and public perception issue. Some impacts may not be quantified until several years after construction or initial operations. The general public's basic understanding of groundwater is often limited and their concerns focus on something they physically cannot see. This paper advocates taking a proactive approach to monitoring by evaluating any need for monitoring and explaining to the public and regulators up front how any potential impacts will be monitored and evaluated. When specific monitoring guidelines are lacking, an advantage can be seized with a proactive monitoring program that allays the public's fears and presents regulators with a defensible and scientifically sound program protective of public health and the environment. Significant cost savings can be realized using several well chosen indicator parameters. If impacts are recognized at a later date, then a more comprehensive list of parameters can be adopted and included for sampling.

## THE PROACTIVE APPROACH

For many years, groundwater was "out of sight and out of mind." The general public took it for granted that "drinkable" groundwater was an assured right and would always be available. Dramatic front page headlines about hazardous waste and toxic chemicals have heightened the public's awareness of the problems with contaminated drinking water. However, because groundwater flow is still "out of sight" and at times an abstract concept, the general public's understanding of groundwater movement and contamination is often limited. When any new linear facility or expansion of an existing one is proposed, a principal concern is often "Will my drinking water be affected?" Often times, the specter of "hazardous waste" or "groundwater impacts" is used by project opponents to block or stall projects that actually have negligible impacts on groundwater resources.

A groundwater monitoring program is commonly used to evaluate potential impacts and changes on ambient groundwater conditions. These changes are measured either quantitatively or qualitatively and any deviations or trends from ambient conditions can provide a warning system so mitigative measures can reverse or rectify the deviation in order to preserve the ambient conditions. A successful monitoring program evaluates the need for monitoring, documents present conditions prior to any change in groundwater usage and continues to monitor for potential impacts.

Therefore, it can be in a proponent's best interests to take a proactive approach in proposing an effective monitoring program that meets project objectives and educates and addresses the general public's concerns. A scientifically sound monitoring program proposed at the outset of the project will reduce public skepticism and foster a better spirit of cooperation compared to a program forced upon the project by the public response period. A program presented at the outset shows that the proponent is not trying to hide something or pull a "fast one".

Another benefit of the proactive approach can be quicker regulatory acceptance. Groundwater regulations relative to right-of-way projects often involve overlapping regulatory authorities, each concerned with a particular element or facet of the right-of-way. A composite monitoring program therefore, is more apt to "fall through the cracks" or be subject to delays in review compared to more traditional groundwater monitoring programs associated with specific types of "nonlinear" projects such as underground storage tanks, landfills or RCRA (Resource Conservation and Recovery Act) permitted sites. Discussions with several state agencies confirmed that given the lack of specifically applicable monitoring regulations to right-of-way projects, most monitoring programs would be evaluated on a case-by-case basis. State agencies have a primary purpose of protecting the public and the environment; a properly presented and well thought out monitoring program is more likely to receive timelier regulatory approval from the applicable reviewing agencies than a "consensus" program generated by a committee of various state officials, each focused on their particular area of authority.

## GROUNDWATER MONITORING PROGRAM ELEMENTS

The primary elements of a typical groundwater monitoring program are:

- Conceptual Site Model
- Measurement Points
- Measurement Parameters
- Measurement Frequency

The following discussion examines each of these elements.

### Conceptual site model

A conceptual model is a construct used to represent or approximate the field conditions of the site. It is based on the site specific and regional observations and theories about the aquifer and its properties (porosity, hydraulic conductivity, storativity). It answers (or attempts to answer) questions such as what are the ambient groundwater levels?; what are the aquifer materials and properties?; what direction is groundwater flowing and how fast is it traveling?; how much precipitation recharges the aquifer or runs off to streams and surface water bodies?; how is this aquifer connected to the bedrock, to other wells in the area or other surrounding areas? A good conceptual model shows both the public and regulatory community that you understand the local area and that the groundwater regime in question is not a generic "black box". As will be shown below, a good conceptual model is essential to selecting the most appropriate monitoring points, minimizing the number of parameters sampled and supporting a reduced frequency for monitoring.

In some cases, the conceptual model can actually be used to support the case for no monitoring program. This could occur if project activities are so well defined and the aquifer properties definitized such that the consequences of implementing project activities would have no measurable impact on the groundwater regime.

### Measuring points

A fundamental issue in the development of any monitoring program is the selection of locations for monitoring wells and sampling stations. The conceptual model provides an understanding of groundwater movement and should be used to select locations where potential impacts would be first recognized, e.g., downgradient of a potential release site or at the property boundary closest to the right-of-way. The sampling point should also be located close enough to the potentially affected area to provide adequate time to evaluate any impacts and provide mitigation where appropriate. Because groundwater resources can be located in both bedrock and overburden aquifers, the monitoring points must also be located in the appropriate aquifer unit. If residential wells might be affected by proposed right-of-way activities and these residential wells are located in a sand and gravel aquifer, then the monitoring point(s) should be located in the same formation and placed between the facility and the residential wells. For long segments of linear facilities such as pipelines, one or two representative measuring points can be utilized for the entire segment.

Newly constructed or drilled wells provide an assurance of well integrity and location in the specific areas of interest. In many cases, existing wells from other explorations or monitoring programs can also be utilized provided they are appropriately constructed and located in the area of interest. Geotechnical borings installed during initial site planning and construction work can easily be converted to monitoring wells at the outset and thus, provide a savings in later construction costs if they are located in the appropriate area (refer to the conceptual model).

Where possible, monitoring wells should be located within the right-of-way or on station property to provide adequate security and confidence that the wells will not be tampered with or destroyed. If wells must be located outside of the proponent's property control, agreements should be negotiated to provide uninterrupted access. Appropriate security measures should then be taken to protect the wells (locking protective covers or low visibility, flush mounted road boxes). Note that if residential water supply wells must be included in the monitoring network, they pose potential liabilities from a physical measurement standpoint (well depth, water levels and other downhole probes). Any measurement activity requiring the insertion of equipment into the well or borehole or removal of a well pump and piping may invite a damage claim if well performance or water quality change following the measurement event. These wells can usually be sampled safely for chemical parameters from a faucet or tap without affecting the performance of the well.

Each project should also include at least one background monitoring well. This well is usually located hydraulically upgradient of any activity (based on the conceptual model). This apparent upgradient monitoring station is presumed to be unaffected by right-of-way activities and should document any regional changes in water quality or parameters not attributable to the proponent's activities. Be careful in the selection of the background well to make sure that it in turn is not going to be affected by other activities both within and outside of the right-of-way (e.g., your background well is located in the plume of an adjacent landfill).

### Measured parameters

The goal of monitoring is to measure differences or contrasts between existing and future conditions. To that end, a limited group of selected indicator parameters can be identified to recognize these changes. Once changes are recognized, a more extensive list of analytical parameters can be developed to quantify the specific impact. Measurement parameters can be divided into physical and chemical subgroups. Examples of physical parameters include water level, total suspended and dissolved solids, turbidity, temperature, well yields and pumping rates. Chemical parameters include those that measure chemical properties such as specific conductivity and alkalinity as well as those that measure specific compounds and analytes.

Wherever possible, water levels should be measured in available wells to generate the most complete potentiometric (water level contour) map possible for each water bearing zone or aquifer (e.g., shallow overburden, bedrock, confined aquifer, etc.). This map will allow recognition of fluctuations in water level, flow gradients, and groundwater flow direction. This map then becomes an essential component for updating and validating the conceptual model.

Recent advances in instrumentation and field analytical methods now allow measurement of many physical and chemical parameters in the field using probes, colorimetric, immunoassay and other techniques. The advantages of field measurements are that multiple samples can usually be collected, measured and analyzed the same day as opposed to being sent for more time consuming and costly offsite laboratory analysis. The drawbacks are usually increased detection limits and, for some analytes, qualitative instead of quantitative results (i.e., presence or absence of an analyte). It should be noted that field analyses often require specific analytical skills and may also require a brief development period for the specific monitoring application. It is also a good practice to select a percentage of samples for offsite analysis to confirm the accuracy of field results.

Several of the more popular indicator parameters are described below:

*pH*

A logarithmic measurement of the hydrogen ion activity (usually in the form of the negative base 10 log of the activity). The hydrogen ion activity is controlled by various interrelated chemical reactions that either generate or consume hydrogen ions (Hem 1985). Thus, it can reflect changes in groundwater chemistry attributable to ongoing chemical reactions.

*Specific conductance*

A measurement of the ability of groundwater to conduct an electrical current over a unit length and cross section at a specific temperature (Hem 1985). The presence of charged ionic species increases the conductance of groundwater. Thus, a change in the specific conductance is indicative of a change in the ion concentrations of the groundwater constituents.

*Temperature*

Temperature fluctuations in groundwater usually exhibit a dampened response and are often seasonal in nature. Widely varying or rapid fluctuations in temperature may be indicative of mixing with or introduction of other groundwater sources.

*Turbidity*

Turbidity refers to the total suspended particles (organic and inorganic) in a groundwater sample and is measured by the amount of light these particles will transmit or scatter when a beam is passed through a sample. Large changes in turbidity in a bedrock system may be indicative of a change in flow path through the fractures. Large changes in turbidity may also arise from the accumulation of small particulates and formation materials passing through the well screen and into the well.

*Dissolved oxygen*
Oxygen is readily consumed in the reduction and breakdown of a variety of chemically reduced constituents. Changes in dissolved oxygen levels may be indicative of either changes in recharge (i.e., more oxygenated water is reaching the aquifer from precipitation) or constituent chemistry within the groundwater (i.e., more oxygen is being consumed to reduce additional constituents in the groundwater).

### Measurement frequency

The frequency of sampling is an important consideration in any groundwater program; unfortunately there is no universal answer. Regulatory programs can require weekly, monthly, quarterly or annual sampling and reporting rounds. In the absence of any specific regulatory requirements, the site hydrogeologic properties described in the conceptual model can be used to establish a proposed monitoring schedule for the particular right-of-way activities. If monitoring is keyed to a specific site event (e.g., a materials release), the travel time for a potential release or impact occurrence to reach a monitoring well or the property boundary can be estimated using the conceptual model. The monitoring interval can then be adjusted to include time for detection and recognition of any changes in the groundwater regime. For example, if groundwater moves at an extremely slow velocity, and it will be years before any impact is recognized at the monitoring point, it may not be imperative to have a high frequency monitoring schedule.

Wherever practicable, baseline conditions should be measured, preferably for several rounds prior to the scheduled activities. This will permit any near or long term trends (e.g., drought conditions, rising water levels or chemical changes) to be recognized, quantified (where possible) and not inappropriately attributed to project activities.

## EXAMPLE MONITORING PROGRAM APPROACHES

Many right-of-way projects face similar monitoring issues during construction and operation. Some of the more frequently encountered situations include, blasting, construction dewatering, sewerage disposal, materials releases and herbicide applications. Each of the following subsections provides a brief potential monitoring approach and suggests a selection of potential indicator parameters for the particular scenario.

### Blasting

Homeowners get worried that construction blasting of rock and ledge for right-of-way projects will close off or collapse the water bearing materials and fractures that supply water to their drinking wells. However, many private water supplies are located in sand and gravel types of deposits so the well is recharged by precipitation or stream inflow and not from fracture flow through bedrock. For these types of situations, the conceptual model can be used to illustrate the aquifer interconnections and defuse the homeowners' worries; a monitoring program may not be necessary. If the private water supply well is located in bedrock, and there is sufficient public concern, a representative monitoring well can be constructed on the right-of-way property prior to blasting and monitored both before and after the blasting. Any impacts from the blasting (fracture collapse) would presumably be detected in this onsite monitoring well first based on its proximity to the blasting area. Where possible, this well should be located in the same fracture system supplying the residential wells.

Indicator parameters should focus on yield and detecting any physical/chemical changes in the water supply. Well yield (specific capacity) in terms of a pumping rate per unit of drawdown (gallons per minute per foot) should be quantified and water level, pH, specific conductance, temperature and turbidity can be measured. A significant drop in yield along with changes in the measured parameters could be indicative of changes in the source of water to the wells. Homeowner wells should also be measured where possible for at least specific conductance, temperature and pH. Well yield and water depth may not be quantifiable based on the presence and type of pumping equipment in the well (see note in the section on Measuring Points). Additionally, available drilling logs or well construction details (depth of well, open borehole length, specific capacity at time of installation) should be obtained from the owner if available.

### Construction dewatering

Construction dewatering raises concerns about impacts on water supplies as well as impacts on surrounding wetlands and water bodies. A good conceptual model can be used to recognize potential hydraulic connections between the site and either a homeowner or affected wetland. The conceptual model will also allow some prediction to be made about potential drawdowns using a simple analytical approach. The estimated and measured aquifer parameters used to construct the conceptual model can be substituted into analytical equations to estimate drawdowns and dewatering rates (see Powers 1992). A network of monitoring wells (and staff gauges in wetlands) with water levels measured on a regular basis, can quantify the impacts and permit any necessary revisions to estimates. It is particularly important to document antecedent (preactivity) conditions as there may already be existing seasonal or declining trends in water levels that are not associated with project activities. Declining well yields if measured may be interpreted as corroborative evidence for adverse impacts from dewatering instead of the seasonal variation or established trends that they actually represent.

### Sewerage and wastewater discharge

At compressor stations or other locations where sanitary facilities must be maintained, and local sewerage service is not available, onsite disposal through septic tanks and associated leaching or tile fields is often utilized. Citizens may be concerned about potential effluent contamination of water supply wells and natural habitats. A groundwater potentiometric map (water level contours) will indicate groundwater flow direction so flow towards any sensitive receptors (residential wells or wetlands) can be recognized. Monitoring wells placed between the discharge point and receptors can monitor specific conductance, temperature, pH and ionic species such as nitrate, ammonia or chloride. These ionic species are strongly associated with sanitary waste and can be measured colorimetrically or with ion specific probes.

### Material releases

There is a potential for material releases during construction or facility operation when materials are shipped or used in routine activities. Spill prevention, containment and control plans usually provide for safe operating practices and mitigative measures. Any monitoring should be specific to the particular materials involved.

Although polychlorinated biphenyls (PCBs) are no longer actively used in the utility industry, decommissioning and removal of pipelines or abandoned transformers and substations may turn up residual PCBs. Immunoassay test kits are available that can qualitatively determine PCBs presence (by recognizing absence below a particular detection limit). The cost per sample over a large number of samples is cheaper than laboratory analysis. However, there is a capital equipment investment cost (approximately $2000), a definite analytical technique to master, and the test is specific to certain PCBs congeners. Similarly, immunoassay test kits are also available for Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH). The same caveats noted for the PCB kits also apply to the TPH and PAH kits — the test is responsive to only specific compounds in these groups which then indicate the absence of TPH or PAH at a particular threshold level. These kits do not work well on older spill areas or weathered petroleum sites where the particular indicator compounds have been biodegraded or altered.

### Herbicide application

A potential concern during right-of-way maintenance activities, is likely to be the possible impacts of herbicide applications on groundwater resources. (This problem is not limited to just groundwater resources; there is also a concern for overland runoff of herbicides to streams and waterways.) Most of the currently used herbicides are specifically designed to break down rapidly and minimize any possible unintended adverse environmental impacts. However, convincing local property owners in the vicinity of the right-of-way management area of this fact may be another matter.

Unfortunately, the recent trends toward increasing chemical specificity in herbicide design tends to work against the use of simple field or laboratory screening techniques to monitor groundwater herbicide concentrations. There are a wide variety of organic chemicals which are currently used as the active ingredients in herbicides and they differ significantly in terms of chemical components and structures. Gas chromatography and high pressure liquid chromatography (HPLC) are among the more routinely used laboratory techniques for herbicide analysis. However, herbicides can present unique analytical difficulties, including the need for specialized sample preparation methods and instrumental operating conditions, particularly at low concentrations. Therefore, general organic screening techniques including gas chromatography with mass spectrometry, may often be inappropriate for herbicide analyses. In most cases, it is necessary to identify the specific herbicides of concern. Close communication with the analytical laboratory is essential to carefully delineate the intended project objectives and appropriately design the analytical program. Analytical approaches may differ markedly depending upon whether the goal is to demonstrate the absence of residual concentrations from past herbicide usage in a right-of-way area or to monitor the effect of future applications.

## SUMMARY

Groundwater monitoring programs designed for right-of-way activities and facilities and should be tailored to the nature of right-of-way operations with respect to the local area and hydrogeology. A proactive approach launched early in the planning, permitting and construction phases of the project builds goodwill and trust with the general public by demonstrating a concern for the environment and protection of public health. In some cases, this proactive approach can be used to support an argument for limited or no monitoring based on the right-of-way activities. The proactive approach can also be cost effective by promoting regulatory acceptance and decreasing lengthy review time in the absence of specific monitoring requirements. Any evaluation of the need for a groundwater monitoring program should include at a minimum, the following fundamental elements:

- Development of a site conceptual model;

- Evaluation of area specific hydrogeology to establish measuring locations and sampling frequency;
- Careful evaluation of site chemistry to establish proper analytical programs and measurement frequencies.

Potential impacts need to be explored and understood within the structure of the conceptual model. This understanding can then justify the use of less expensive indicator parameters and decreased frequency of monitoring based on the time for potential impacts to be detected or to support the argument that monitoring is not necessary based on the proposed right-of-way activities.

## ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of the following Foster Wheeler Environmental colleagues in the preparation of this paper: Dr. Lewis Horzempa for his contributions on field chemistry and overall review; Ms. Helen Douglas for her contributions on herbicide analyses; and Ms. Kathleen Docherty for her contributions on state monitoring requirements for right-of-way facilities.

## REFERENCES

Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. 3rd edition. Water-Supply Paper 2254. U.S. Geological Survey, Alexandria, Virginia. pp. 61–66.

Powers, J.P. 1992. Construction Dewatering: New Methods and Applications. 2nd edition. John Wiley and Sons, Inc., New York, pp. 94–106.

## *BIOGRAPHICAL SKETCH*

***Boyd Allen III***

*Sciences Manager, Foster Wheeler Environmental Corporation, 470 Atlantic Avenue, Boston, MA 02210, USA*

Mr. Allen is the Geosciences Discipline Leader for Foster Wheeler Environmental Corporation and also serves as the Sciences Manger in the Boston office. He is a certified professional geologist and his technical interests include groundwater movement, aqueous geochemistry, contaminant fate and transport, and glaciology and ice chemistry. He has a bachelor's degree in Geology from Colby College and a master's degree in Earth Sciences from the University of New Hampshire.

# Minimizing the Risk of Contaminated Soils in Pipelining

**Mario E. Buszynski**

Owners of gas pipelines that use the public roadway for their facilities may encounter contaminated soils when constructing the pipeline. This situation has resulted in increased costs and delays in the construction schedule. The paper outlines a process, similar to a Phase I Environmental Site Assessment, that identifies areas of high potential for contamination from various sources. The number and location of potentially contaminated sites are then factored into the route selection process. A case study of a pipeline in southern Ontario, Canada, is used to illustrate the methods described in the paper. Procedures are outlined to effectively manage these situations if they cannot be avoided. Recommendations are made as to the transferability of this process to other jurisdictions.

*Keywords*: Contaminated soils, environmental assessment, hydrocarbon contamination, preferred route

## INTRODUCTION

Steel pipe used in the transport of natural gas has exterior coatings which are applied to prevent or reduce corrosion. In many cases, the type of coating used is called "yellow jacket". It is put on over a thick adhesive previously applied to the exterior of the pipe to secure the coating. Contaminated soils, especially those containing hydrocarbons, can destroy the adhesive, causing the exterior coating to hang loosely on the pipe and actually help to increase corrosion in the affected area. Hydrocarbon contamination can also affect certain joint tapes (e.g., coal tar) in the same fashion. Figure 1 shows a typical "yellow jacket" pipe being installed in a public road allowance.

Hydrocarbon contaminated soils are frequently encountered in distribution pipeline construction since smaller diameter, extra high pressure 150 mm (6 in) to 323.9 mm (12 in) diameter pipelines are easily accommodated in the public roadway. In many situations, old or abandoned gas stations adjacent to the pipeline route are located over pools of hydrocarbon contamination from leaking underground storage tanks. Other land uses such as waste disposal sites and chemical processing plants adjacent to the public roadway represent potentially contaminated sites. Figure 2 illustrates a leaking underground storage tank being removed from the ground. Figure 3 illustrates an area where contaminated soils are being removed from the site. Note the gas pipeline being supported by a wooden brace in the foreground of the photograph.

When contaminated soils are encountered during pipeline construction, the excavated material must be removed from the trench and disposed of in an approved disposal site. Additional protective measures must be taken which may include wrapping the pipeline in a bentonite (clay) cloth prior to backfilling with clean material. A plastic vapour barrier may also be placed around the pipeline. Even with these precautions the coating may be affected by hydrocarbons infiltrating through the new material.

Many pipelines in urban areas are constructed through the use of directional drilling and boring. Unless contamination is discovered at the tie-in holes, or has been previously identified through a review of surrounding land uses, the only way that small areas of contamination may be identified on a long bore (200–300 m) is by monitoring the drill fluids, a practice not routinely done. The result is that the pipeline could be subjected to increased corrosion which will reduce its service life.

This paper presents a method used to minimize the risk of encountering contaminated soils in pipeline route selection. It is done through a case study of a pipeline which was located in southern Ontario, Canada.

Fig. 1. A typical "yellow jacket" pipe.

Fig. 2. A leaking underground storage tank being removed from the ground.

Fig. 3. Contaminated soils are being removed from the site.

## BACKGROUND

Distribution pipeline planning studies in Ontario are regulated by the Ontario Energy Board (OEB) under the Ontario Energy Board Act, R.S.O. 199, c.O.13. The "Environmental Guidelines for the Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario" (Ontario Energy Board, 1995) provide guidance to proponents undertaking pipeline routing studies in Ontario. The identification and avoidance of contaminated soils is not addressed in this guidance.

Jacques Whitford Environment Limited (JWEL) was retained by The Consumers' Gas Company Ltd. (Consumers Gas) to conduct a route selection, environmental and socio-economic impact assessment (EA) study. The goal of this study was to find a suitable location for a 219 mm (8 in) diameter pipeline to reinforce the existing gas supply to Dufferin and Simcoe Counties and the Caledon and Orangeville areas of Southern Ontario.

A large component of JWEL's work involves the identification of potentially contaminated sites (Phase I Environmental Site Assessment) and site characterization and remediation (Phases II and III). It was felt that the identification of potentially contaminated sites is a significant factor in the planning process, so it was decided to incorporate this site assessment experience into the Orangeville Reinforcement Study.

### The study area

The area chosen for study is located in southern Ontario, approximately an hours drive from Metropolitan Toronto (Fig. 4 and 5). The study area, approximately 1,000 km$^2$ in size, is located between Orangeville and the TransCanada Pipelines right-of-way paralleling Highway Number 400. It is set in an area that possesses significant natural and cultural features, including:

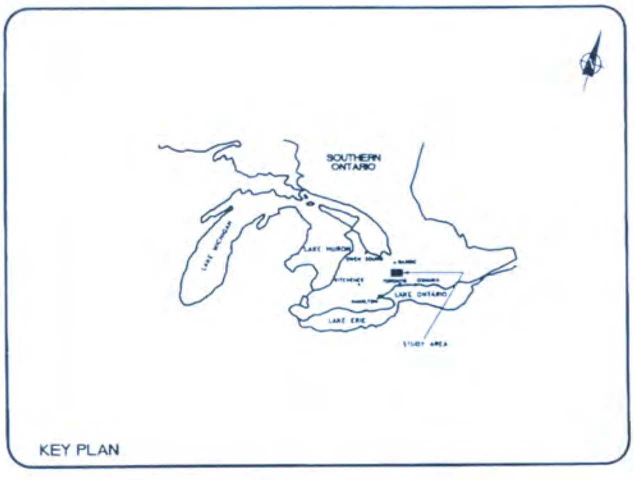



Fig. 4. The study area.

- The Niagara Escarpment, designated as a World Biosphere Reserve, runs through the study area in a north–south direction;
- The Oak Ridges Moraine, a provincially significant feature, is the source area for several rivers that support cold water fisheries in the Greater Toronto Area;
- High quality agricultural lands and large farm operations occupy the central and eastern portions of the study area;
- Provincially significant wetlands and areas of wildlife habitat are scattered throughout; and,
- The beautiful scenery, combined with a rural environment in close proximity to the Greater Toronto Area has created a large group of residential commuters living in the rural parts of the study area while the many towns and villages attract local artisans and industry such as the Honda Motor plant in Alliston.

Figure 5 provides a more detailed location map of the study area.

Many of the regulatory agencies indicated that they expected the pipeline to be located in a public road allowance or other existing linear right-of-way (ROW) to minimize impacts to the environment.

Preliminary research indicated that public road allowances would be the only alternatives, since no other existing ROWs were suitable.

Our research also indicated that all roads in the study area, ranging from Provincial Highways to County roads to Township roads, had the potential to support adjacent land uses which could result in contaminated soils. A process was required to identify these areas of potential soil contamination and factor them into the route selection process.

## PLANNING PROCESS

The process used to identify potential areas of soil contamination is based on the requirements of the Canadian Standards Association (CSA) Phase I Environmental Site Assessment Information Product (Z768-94, April 1994, CSA protocol) and consists of the following:
- A records review;
- A site visit;
- Interviews with regulatory officials and personnel associated with the subject and adjoining properties; and
- Evaluation of information and preparation of a report.

A Phase I ESA does not include sampling or testing of air, soil, groundwater, surface water or building materials. These activities would be recommended at the construction stage.

### Records review

Typically, a Phase I Assessment is conducted for an individual site. In this case, the assessment was conducted over the entire length of the identified alternative routes;

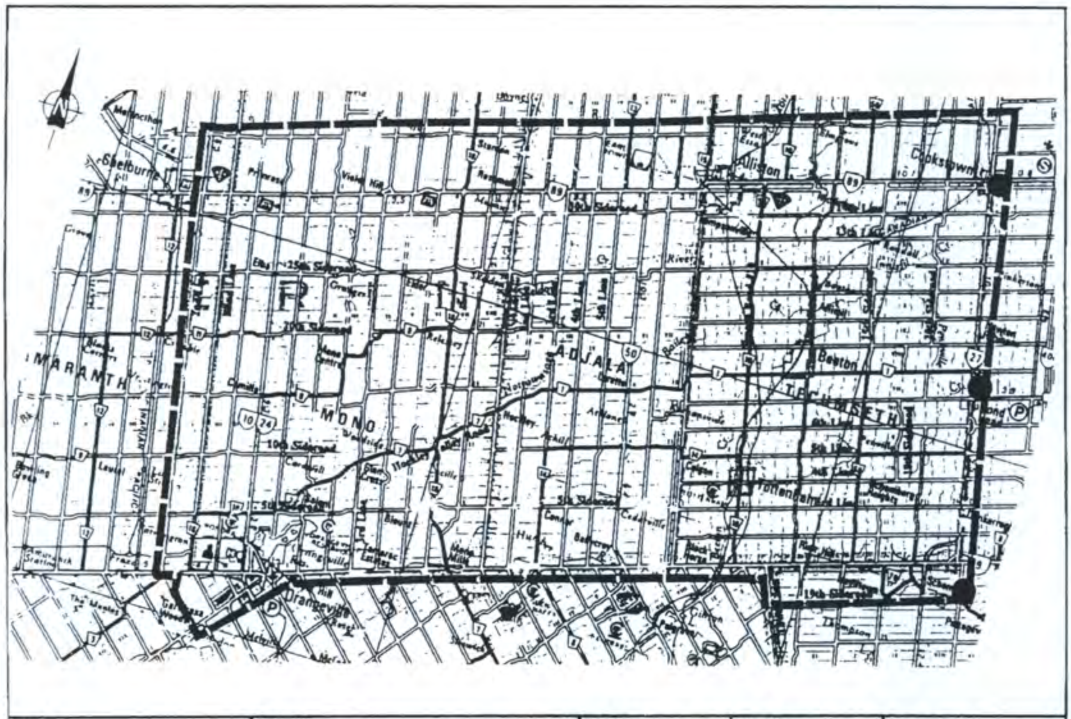



Fig. 5. Detailed location map of the study area.

however, it was not practical to conduct the assessment over every property within the 1,000 $km^2$ study area. When a suspect site was identified, a records review was undertaken. The applicable distance for the records review included properties immediately adjacent to the subject site and other properties through which the pipeline ROW might cross (as identified by aerial photographs, insurance records, etc.) The records review included the following:

- Review of historical and present-day aerial photographs, land registers and Fire Insurance Plans (if available for site) to determine previous land uses and occupancy;
- Discussions with the municipal planning department regarding historical construction of buildings on or surrounding the property;
- Review of geological and topographic maps to determine physical site characteristics, such as direction of groundwater flow; and
- Contact with the Ontario Ministry of Environment and Energy (MOEE) and Freedom of Information (FOI) officials regarding past environmental concerns (regulatory infractions search, reportable spill occurrences, and Regulation 347 Regulation-waste generators).

### Site visit

The alternative routes were surveyed by an individual experienced in identifying existing and abandoned sites with uses that may have generated contaminated soils. These suspect sites were recorded through photographs and entered into the data base for that particular alternative route. The site was described in terms of location, on-site buildings and structures, soil, topography and drainage. Since staff were not authorized to enter onto any of these properties, observations were made from the exterior of the buildings and no soil samples or other "intrusive" investigations were made.

### Interviews

Interviews with local property owners were conducted at the public open house meetings held in connection with the study. In addition, during the evaluation of alternative routes, local residents were questioned as to their knowledge of past spills or groundwater contamination at the sites. For example, a property owner near one of the sites adjacent to the preferred route indicated that there were a number of hydrocarbon spills associated with the use of the property as a gas station.

### Evaluation of the information

The information on hydrocarbon-contaminated sites suspected of having the potential to adversely affect pipeline coatings was assembled and tabulated for each of the three alternative routes identified in the study area. The North Route, which made use of a significant portion of Highway Number 89, had eight potentially contaminated sites. The Central Route, which for the most part was located along Township Roads, had two potentially contaminated sites. The South Route, which was primarily located on Highway Number 9, had sixteen potentially contaminated sites.

This information was placed in a table which included biophysical constraint information such as the number and type of watercourses and wetlands crossed and socio-economic information such as the number of residences, farms and commercial operations affected.

The information on potentially contaminated sites strongly supported the selection of the Central Route Alternative. This information, which was consistent with the strong public and agency support for this alternative, resulted in the Central Route being chosen as the preferred route.

## THE APPROVAL PROCESS

The environmental report was prepared and submitted for approval to the Ontario Energy Board. One Board member's question found in transcripts from the Public Hearing indicate that the issue of contaminated soils was a concern to the Board, in spite of their lack of existing guidance on the subject:

> "Q. My last question. You identified areas of possible soil contamination and I note in the evidence that there will be use of plastic pipe by Consumers. I am wondering whether or not you have indicated any mitigation techniques that might occur, given the new evidence about plastic pipe problems of leakage and permutation with organic compounds and whether or not this would be a problem if plastic pipe were to be laid over areas of soil contamination?" (Ontario Energy Board 1966).

Discussion ensued on the program for managing the two potentially contaminated sites identified along the Preferred Route. Management included the hiring of a full-time environmental inspector and a due diligence program including the testing of the soil on the ROW adjacent to these locations. This was satisfactory to the Board and the project was subsequently approved.

## THE CONSTRUCTION PROGRAM

The two areas of potential soil contamination along the preferred route were associated with gas stations adjacent to the pipeline route in the communities of Bond Head and Loretto. The construction program for pipe installation in these areas consisted of directionally drilling the pipe into place. Since the trench would not be open, it was decided, as part of the due diligence program, to conduct test pitting in the vicinity of the ROW to determine if any contamination was present.

Fig. 6. Test pitting at Bond Head with the gas station in the background.

Fig. 7. The environmental inspector taking vapour readings from the soil samples to determine the presence of hydrocarbon contamination.

Figure 6 illustrates the test pitting at Bond Head with the gas station in the background. As the test pit was dug, soil samples were taken at various depths. Figure 7 shows the environmental inspector taking vapour readings from the soil samples to determine the presence of hydrocarbon contamination. Visual observations were also made for staining of the soil. Readings at both locations came up negative, although readings taken some distance from the ROW in Bond Head indicated the possibility of hydrocarbon contamination in the soil.

## SUMMARY

Soil contamination has been proven to be detrimental to certain high pressure gas pipelines in that it can affect coatings, leading to accelerated corrosion and shortened pipeline life. In order to minimize the potential for encountering contaminated soils in pipeline route selection, an assessment of the types of land uses that can result in contamination should be performed at the data collection phase of the project. This information should be factored into the alternative route identification and selection of the preferred route to minimize costs associated with the mitigation of contaminated soils. The advantages of selecting a route which minimizes the number of sites with potentially contaminated soils includes reduced construction time and costs for remediation. While this assessment will be only one of a number of factors used to identify alternatives and select the preferred route, it should receive a significant weight in the process due to the costs associated with mitigation. The process used is directly applicable to other jurisdictions. International standards and other North American standards have been developed that are similar to the CSA standards for conducting Phase I ESAs. It is a simple matter to undertake this work and factor it into the selection of a preferred pipeline route.

## ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of Marika Hare, Director of the Environmental Affairs Department of Consumers Gas and Mike Brophy, a member of that Department, during the pre-approvals process. The assistance of Mr. John Kordan, Construction Superintendent for Consumers Gas Western Region is acknowledged during the post-approvals process.

## REFERENCES

Consumers Gas. 1994. Environmental Management Manual For Environmental Protection During Pipeline Construction, May 1994.

Jacques Whitford Environment Ltd. 1996. Route Selection, Environmental and Socio-Economic Impact Assessment, Supply to Orangeville. January 1996.

Ontario Energy Board. 1995. Environmental Guidelines For The Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario, Fourth Edition.

Ontario Energy Board. 1996. Farr & Associates Reporting E.B.L.O 256, E.B.A 737, E.B.C. 246. 5 June 1996, p. 152.

---

## *BIOGRAPHICAL SKETCH*

***Mario Buszynski***

*252 Glenforest Road, Toronto, Ontario, Canada M4N 2A4*

Mario Buszynski, M.C.I.P., R.P.P., has a B.A. in Geography and a Masters in Forestry, both from the University of Toronto. He is a full member of the Canadian Institute of Planners. Fifteen of his twenty-one years of experience have been spent conducting planning and assessment studies for more than 4,000 kilometres of gas and electric facilities in Canada, the United States and overseas. He was the Manager of the Environmental Sciences Division in Jacques Whitford Environment Limited at the time the paper was written. He has recently moved to a comparable position with Beak International which is a company that has a longer history of providing environmental services to the pipeline industry.

# Third-Party EISs for Federal Approvals of Pipeline Projects

**David F. Jenkins**

The third-party process as defined in the National Environmental Policy Act (NEPA) of the United States provides a mechanism for a Federal regulatory agency to use a consultant paid for by the pipeline applicant (or proponent) to prepare the Environmental Impact Statement (EIS) to meet the agency's NEPA requirements. The consultant works at the direction of the Federal agency with limited contact with the pipeline company. The third-party process offers advantages to a pipeline company when a qualified consultant can be used to assist a Federal agency with limited funding or staff resources. However, the Federal agency must be able to provide adequate direction to the consultant to ensure that adequate NEPA documents are prepared. Care must be taken in the third-party process to manage changes to the contract between the pipeline company and the consultant when the consultant is working only at the direction of the Federal agency.

*Keywords:* National Environmental Policy Act, NEPA, Environmental Impact Statement, EIS, Third-party process, pipelines

## INTRODUCTION

The National Environmental Policy Act (NEPA) (Pub. L. No. 91-190 [1970], as amended by Pub. L. No. 94-52 [1975], and Pub. L. No. 94-83 [1975] [codified as amended at 42 USC § 4321-47]) of the United States (U.S.), which became effective on 1 January 1970, established a national environmental policy (42 USC § 4331-32; 40 CFR § 1500.1) and created the Council on Environmental Quality (CEQ) to administer the act (42 USC § 4341-43). The CEQ initially established guidelines for the preparation of environmental impact statements (EISs) (35 Fed. Reg. 7,391 [1970]; 36 Fed. Reg. 7,724 [1971]; 38 Fed. Reg. 10.856 [1973]; 38 Fed. Reg. 20,550 [1973]) and ultimately issued regulations in 1978 to make the EIS a more effective decision-making document (40 CFR § 1500-08).

Under NEPA, U.S. Federal agencies are to prepare EISs for inclusion in "every recommendation or report on proposals for ... major Federal actions significantly affecting the quality of the human environment" (NEPA § 102[2][C], 42 USC § 4332[2][C]). As part of the process, the Federal agency must determine if an environmental assessment (EA) or an EIS is required (40 CFR § 1501.4). If an EA is required, the Federal agency may prepare the document or allow the applicant (the company or entity proposing a project or action) to prepare the document (40 CFR § 1506.5[b]). Some Federal agencies allow the use of a "third-party contract" for the preparation of the EIS. The third-party arrangement involves the contracting by the applicant of a consultant "chosen" by the Federal agency to prepare the EIS (Council on Environmental Quality 1981). However, the Federal agency must independently evaluate the EIS prior to its approval and take responsibility for its scope and content (40 CFR § 1506.5[c]). The application of the third-party process to the Federal permitting of a pipeline can offer both advantages and disadvantages to the project applicant in terms of a timely review of a proposed project and receipt of the necessary Federal permits.

## THE THIRD-PARTY PROCESS

The third-party process involves the use of a private-sector or commercial contractor to assist the Federal agency when the agency cannot prepare the required NEPA analysis because of time, budget, or other limitations, or when the agency or a project applicant requests the use of a contractor to prepare an EIS. The term "third-party contract" refers to the fact that the applicant for the proposed project awards the contract and pays the contractor for the preparation of the EIS. The contractor, however, has little if any contact with the applicant, working under the direction of the Federal agency.

Different Federal agencies have different approaches to administering third-party processes to fulfill their obligations under NEPA. Each approach must meet the requirements of NEPA, but each is also designed to meet the objectives and procedures of the individual agency. Several different Federal agencies may become involved in the preparation of an EIS for a pipeline project, depending on the type of pipeline (e.g., natural gas [interstate, intrastate, or gathering], oil, product, water, coal slurry, etc.), the resources affected, and the jurisdiction of the various agencies over those resources. If Federal permits are required and more than one Federal agency has potential jurisdiction over the project, a single Federal agency is designated as the Federal lead agency as defined by NEPA (40 CFR § 1501.5[c]).

For example, the Federal Energy Regulatory Commission (FERC) is typically the Federal lead agency for the licensing of interstate natural gas pipelines. However, if the interstate pipeline crosses federally managed land, the Federal agency that manages those lands (e.g., the Bureau of Land Management [BLM], or the U.S. Forest Service [USFS]) may be designated as the Federal lead agency for purposes of the environmental review of the project. In cases in which the pipeline is not an interstate natural gas pipeline or no Federal lands are crossed, the U.S. Army Corps of Engineers (COE) may be the Federal agency if other than a nation-wide permit is required. Many of these agencies have defined third-party procedures.

In February 1994, FERC announced the beginning of a voluntary third-party contracting program to assist the agency in reviewing the environmental aspects of applications and preparing the environmental documents required by NEPA (Federal Energy Regulatory Commission 1994). The program makes provisions for the use of an independent contractor who is: (1) selected and works under the supervision and control of the FERC staff; (2) responsible for conducting environmental analyses and preparing documentation, including EISs; and (3) paid by the project applicant(s). FERC published guidelines that provide specific guidance for the Request for Proposal (RFP) to be developed by the applicant (including an example RFP); criteria for the selection of the third-party contractor; and specific direction to address the issue of potential conflict of interest of the bidders for the third-party contract. The issue of conflict of interest is thoroughly addressed to ensure that the third-party contractor has "no financial or other interest in the outcome of the project" (40 CFR § 1506.5[c]).

The BLM established third-party contracting procedures in 1988 (Bureau of Land Management 1988). The procedures provide guidance for: (1) the development of a Memorandum of Understanding (MOU) between BLM and the applicant; (2) development of a statement of work for the EIS; (3) evaluation of bids from contractors and selection of the third-party contractor (including the conflict of interest review); and (4) the development and review of the NEPA document.

The U.S. Army Corps of Engineers (COE) has also defined procedures to allow applicants to pay for the costs of preparing EISs through the use of third-party contractors (US Army Corps of Engineers 1987). As part of this process, the COE established guidance for third-party contracting to ensure that information obtained through a third-party contract is consistent with the COE's statutory requirements (US Army Corps of Engineers 1988).

The USFS has used a process similar to the third-party process, but with many characteristics of an "applicant-prepared" process, to assist in preparing EISs for projects in national forests. This process has involved: (1) allowing the applicant to take the lead in the scoping process under USFS guidance; (2) providing comment and guidance to the applicant during the preparation of the applicant-prepared EIS; (3) providing comments on the applicant-prepared EIS to ensure conformance with USFS objectives; and (4) allowing the applicant to print the NEPA documents.

A distinction should be made between the "third-party" process and the "applicant-prepared" process. In the third-party process, the Federal agency oversees and directs the efforts of the third-party contractor during the preparation of the EIS. However, in the applicant-prepared process, the Federal agency has no oversight or control during the preparation of the "applicant-prepared" EIS. The applicant-prepared process involves the preparation of an "EIS" by the applicant (with or without the assistance of a contractor) for submittal to the Federal agency. The Federal agency then uses the "applicant-prepared EIS" as the basis for the agency's EIS. The agency may use all or none of the applicant-prepared document during the preparation of its EIS and in meeting its responsibilities under NEPA. While the document prepared by the applicant can be in the format of an EIS with the necessary information, analysis, and conclusions, only the Federal agency can prepare the EIS.

## ADVANTAGES/DISADVANTAGES OF THE THIRD-PARTY PROCESS

The primary advantage of the third-party process to the applicant is that it represents an opportunity for the applicant to accelerate the preparation of an EIS if budgetary, staff, or schedule constraints exist for the Federal agency with responsibility for preparing the

EIS. However, several important issues must be addressed to prevent them from becoming disadvantages to the third-party process.

One of the most important aspects of the third-party process is the selection of a qualified third-party contractor. It is essential to select a contractor that can act as an extension of the Federal agency staff and support the agency staff during the EIS development process so that it meets the agency's obligations under NEPA. The third-party contractor must understand the requirements of the EIS process and how to manage the activities associated with meeting those requirements. This includes managing scoping activities correctly, adequately addressing public comments, dealing with cooperating agencies, analyzing issues at the correct level of detail in the draft EIS (DEIS) and the final EIS (FEIS), developing mitigation measures, and determining which alternatives to analyze and at what level of detail. To be effective in developing the EIS, the third-party contractor must fully understand the processes associated with and the requirements of the construction and operation of pipelines. If the third-party contractor cannot function effectively as an extension of the agency staff, the third-party process may actually result in the EIS preparation taking longer than if the agency staff prepared the EIS themselves.

Given the importance of selecting a qualified third-party contractor, the efforts put into the development of the RFP for the third-party process, the review of qualifications of bidders, and a clear understanding between the applicant and the Federal agency regarding the responsibilities of the third-party contractor are of primary importance. Failure to identify a qualified contractor can have significant consequences on the overall third-party process.

One of the primary advantages of the third-party process to the Federal agency is that the applicant pays the majority of the costs of the EIS preparation. However, use of the third-party process does not mean that there are no costs to the agency. The agency must have adequate staff and resources available to manage the third-party contractor. The third-party contractor must have adequate direction and oversight from the agency staff during the scoping process, data collection/agency contacts, and the development of the Notice of Intent (NOI), data requests, the DEIS, and the FEIS to ensure that the process evolves smoothly and the EIS documents are prepared in an efficient manner. Many agencies have developed their own unique approach to addressing issues in an EIS and handling the NEPA process. If it becomes necessary for the third-party contractor to rework numerous draft documents to meet the agency's expectations or for the agency staff to rewrite the EIS documents, a potentially significant delay can be experienced in the EIS process.

A second aspect of the third-party process that should be clearly understood by the applicant, the Federal agency, and the third-party contractor relates to the issue of changes in the contractor's scope of work during the EIS preparation process. Under the third-party process, the contractor is contracted by the applicant with a defined scope of work, budget, and schedule, but works at the direction of the Federal agency staff. As with most major licensing projects, a scope of work and schedule that are defined early in the process are highly susceptible to change. Not infrequently, the Federal agency staff will determine the need to conduct activities that may be outside the scope of work originally agreed to between the applicant and the contractor. If the project is controversial or if a large number of comments are received proposing a wide variety of alternatives, the Federal agency may wish to explore a wide range of issues and alternatives, well beyond the original scope of work in the applicant's contract with the third-party contractor. These "out-of-scope" activities can result in changes in contract costs to the applicant and can result in a lengthened overall project schedule. Establishing the procedures to deal with out-of-scope activities should be part of the early planning considerations for a third-party contract. Such procedures could be included in an MOU between the applicant and the Federal agency.

A third issue related to the third-party process is the additional (short-term) cost to the applicant associated with payments to the third-party contractor. Different Federal agencies have different mechanisms to finance the costs of EISs prepared by their staffs. Some agencies receive funding through a direct or indirect levy on the companies or industry regulated by that agency. Other agencies directly charge the applicant for the costs of the EIS preparation by the agency staff or rely on their annual budget to fund the preparation of EISs. When the Federal agency prepares the EIS, the applicant may only pay costs incidental to the EIS preparation (e.g., costs of meeting rooms or legal reporters for scoping meetings, costs of helicopters for review of the proposed project route), with the costs associated with the agency staff time and travel paid directly by the agency. The third-party process requires the applicant to pay for all staff time and travel of the third-party contractor as well as printing costs for the EIS documents.

However, these greater short-term costs may result in greater long-term benefits if the third-party process accelerates the approval of the project. For example, if the third-party process results in an in-service date for a pipeline that is a few days or a few weeks earlier than the in-service date without the third-party process, the financial advantages may more than outweigh the short-term costs associated with the third-party process. However, if the third-party process does not result in the acceleration of project licensing, the third-party process may, indeed, result in greater costs to the applicant.

## SUGGESTIONS FOR APPLICATION OF THE THIRD-PARTY PROCESS

The following are suggestions for the use of the third-party process for the licensing of pipelines.

1. Consult as early as possible with the probable Federal agency when planning a pipeline project to determine if the third-party process is recommended by the agency. Although an agency may not require that an applicant use the third-party process, the agency may give clear "signals" that the applicant could benefit if the third-party process is used.
2. Develop a clear understanding with the agency of the various aspects of the third-party contract with a consultant, specifically relating to payment of the third-party contractor, how out-of-scope issues are dealt with, and what contact and communications between the third-party contractor and the applicant are acceptable to the Federal agency.
3. Develop very stringent and detailed criteria for the selection of the third-party contractor. As noted above, the general qualifications of the potential contractors, their experience with the preparation of NEPA documents, their experience with the Federal agency and its procedures and expectations, demonstrated ability to manage large projects, and a thorough understanding of pipeline construction and operation are crucial to successfully supporting the Federal agency in the preparation of the EIS.

## SUMMARY

The third-party process is an approach provided for in the NEPA regulations to attempt to control the costs to the Federal agency for the preparation of an EIS. The process also represents a mechanism for potentially accelerating the EIS preparation process if the agency is constrained by budget, staff, or schedule. However, before entering into a third-party arrangement for the preparation of an EIS for a pipeline, the pipeline company must fully understand the potential advantages and disadvantages of the process relative to the "traditional" process of having the Federal agency prepare the EIS. If properly managed, the third-party process for the preparation of a Federal EIS for a pipeline project can benefit the applicant.

## REFERENCES

Bureau of Land Management. 1988. BLM Manual, Appendix 7. Rel. 1-1547. 25 October.

Council on Environmental Quality. 1981. Forty most asked questions concerning CEQ's National Environmental Policy Act Regulations, 46 Fed Reg. 18,026, 18,031

Federal Energy Regulatory Commission. 1994. FERC News Release issued February 9, 1994. Subsequent announcements were published in the Commerce Business Daily (25 March 1994) and the Federal Register (20 April 1994).

US Army Corps of Engineers. 1987. EIS costs that can be paid by the applicant. Regulatory guidance letter 87-05. 28 May.

US Army Corps of Engineers. 1988. Third-party contracting. Regulatory guidance letter 88-15. 7 November.

---

### *BIOGRAPHICAL SKETCH*

***David F. Jenkins***

*Foster Wheeler Environmental Corporation, 470 Atlantic Avenue, Boston, MA 02210-2208, USA*

David F. Jenkins is a Director, National Oil and Gas Pipeline Programs at Foster Wheeler Environmental Corporation and has over 20 years of experience in siting, impact assessment, and Federal and state licensing of pipeline, electric transmission line, and other energy projects.

# Common Environmental Problems Encountered During Construction of Major Gas Transmission Lines

**David D. Macks, David Morrell, and John Strub**

Beginning with construction of the Iroquois Gas Transmission Line in 1991, Compliance Unit Staff of the Department of Public Service's Office of Energy Efficiency and Environment, has monitored construction of almost 960 km (600 miles) of 30.5–91.5 cm (12–36 in) steel gas transmission line. In each instance, detailed construction plans were submitted to and approved by the New York State Public Service Commission. Detailed records were kept of all requested changes in those construction plans and numerous instances of non-compliance with them as well. Review, categorization and analysis of requested changes and non-compliance reports reveal what staff considers, common environmental problems found during construction. The main problems discovered is that companies often request inadequate temporary ROW or workspace within the certified construction area on slopes, in wetlands and near stream crossings. This creates situations wherein there is insufficient space for separation of topsoils and subsoils in wetlands and active agricultural fields. Insufficient workspace also promotes the unauthorized taking and use of lands outside the certified ROW and the unnecessary pollution of streams due to inadequate workspace for spoil storage. In response to these problems, Staff has modified its construction monitoring, and change processing procedures and is currently revising its in-house construction standards.

*Keywords*: Pipeline construction, ROW width, stream crossings, wetland crossings

## BACKGROUND

Beginning with construction of the Iroquois Gas Transmission Line in 1991, the Field Compliance Unit (FCU) of the New York State Department of Public Service's (Department) Office of Energy Efficiency and Environment, has monitored the construction of approximately 994 km (621 miles) of 30.5–91.5 cm (12–36 in) steel gas transmission line. The gas transmission facilities approved for construction by the New York Sate Public Service Commission (PSC) and used in this study, consisted of four separate pipeline projects which spanned the length and breadth of New York State. They were the:

- Iroquois Gas Transmission System — 590 km (369 miles) of 76.2 and 60.1 cm (30 and 24 in) steel pipeline
- Empire Gas Transmission Line — 253 km (158 miles) of 60.1 cm (24 in) steel pipeline
- Sithe Energy Project - 58 km (36 miles) of 40.1 cm (16 in) steel pipeline
- Seneca Storage Project East — 56 km (35 miles) of 40.1 cm (16 in) steel pipeline
- Seneca Storage Project West — 29 km (18 miles) of 40.1 (16 in) steel pipeline.

The facilities were approved for in-state construction under Article VII of the Public Service Law. Article VII requires applicants who wish to build fuel gas transmission pipelines over 304 m (1,000 ft) and length and 125 psig in New York State, to submit an application to the Department for a Certificate of Environmental Compatibility and Public Need. Granting of a certificate clears the way for construction and, in some cases, grants the power of eminent domain to the applicant.

In addition to approving their construction, the Commission required that each project have an Environmental Management and Construction Plan (EM&CP) submitted and approved prior to construction. This document would describe in detail, how the pipeline was to be built. Realizing that no plans can fully anticipate conditions in the field, a system to approve "minor" changes (MC) to the approved EM&CP was put into place.

Moreover, Staff developed a method of recording "non-compliance" with the approved EM&CP. "Incident Report" (IR) forms were produced, whereby Staff observing problems in the field could record and immediately give responsible company personnel a written record of the problem. In subsequent years IR forms were replaced by new forms in an effort to provide more detail. These new forms, "Non-Compliance Reports" (NCR) and "Violation Reports" (VR), combined with bound field logs, photographs and video tape, provided Staff with extensive documentation of environmental problems observed during construction. Compilation, categorization and analysis of requested changes and non-compliance reports readily reveals the most common environmental problems found during pipeline construction.

The primary environmental problem occurring during pipeline construction is inadequate temporary workspace on slopes, wetlands and at stream crossings. The lack of adequate temporary workspace creates situations where there is insufficient space for separation of topsoil and subsoils in wetlands, active agricultural fields and insufficient area for effective spoil storage at stream crossings. Insufficient workspace also promotes the unauthorized taking and use of lands outside the approved ROW. Additionally, an examination of records show that environmental problems often occur at stream and wetland crossings. In response to these problems, Staff has modified its construction monitoring and change processing procedures and is currently revising its in-house construction standards.

## METHODS

In order to determine the nature and extent of specific environmental problems, MC, NCR, IR and VR were gathered and examined. All documents relating to gas transmission lines 30.5 cm (12 in) or greater in diameter were separated and reviewed. These records were then examined in greater detail and categorized. MCs were sorted according to the nature of change requested and in some instances the urgency of the request. NCRs, IRs and VRs were examined and sorted by the nature of the offense, content and action taken. In addition, field logs were examined for incidents which occurred but may not have warranted an MC or other written response. In that Department generated records represented the entire database, no specific statistic method or model was used. All data were reviewed and those areas which garnered the most attention in the form of in-field modification or compliance action were noted.

## RESULTS

### "Minor change" requests

Nine hundred and twenty four separate requests for minor changes to approved construction plans were made on the projects detailed in this study. A review of requested changes showed the following. Two hundred and eighty-nine modifications or 31.1% of all minor change requests made were for permission to acquire or use "extra workspace" or land adjacent to and outside the approved ROW (see Fig. 1). The next highest categories were requests for off-ROW access roads, 25.1% and storage at 16.7%. There were 100 requested changes, 10.85% of the total, which were unique or so small in number as not to warrant specific categories, these were placed under the heading of "miscellaneous". Stream crossing modifications were 5.8% of the changes requested. Pipeline alignment changes were 5.2% of the total and changes in topsoil stripping techniques comprised the last 3.1%.

### "Non-compliance" reports

The data for enforcement reads differently, of the 318 incidents recorded, 60 or 18.9% involved environmental problems in and around stream crossings (see Fig. 2). This was followed closely by violations concerning wetland crossings at 16.3% and unauthorized

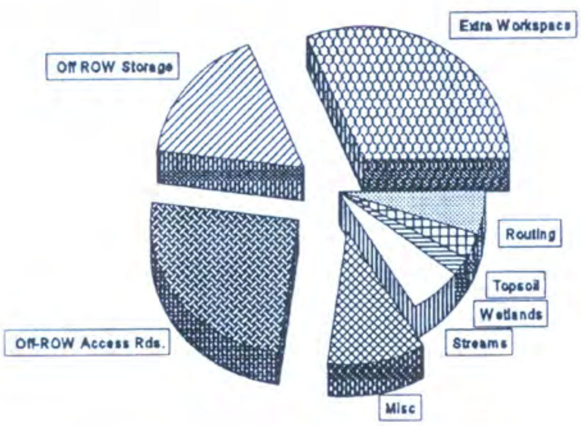



Fig. 1. Minor change requests by activity.

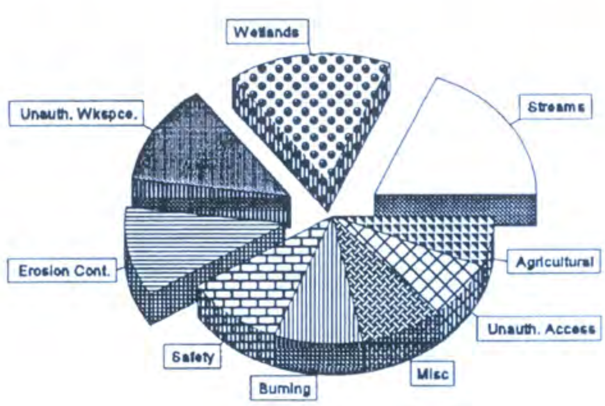



Fig. 2. Non-compliance reports.

use of extra workspace at 12.9%. Compliance actions involving erosion and sediment control measures and aspects of worker or public safety comprise 11.1% and 10.1% of the total respectively.

After numerous problems during construction of the Iroquois project, burning, as a means of removing undesired woody material and slash was severely curtailed by the Department on projects certified under Article VII; nevertheless compliance actions involving some aspects of burning still make up 8.8% of the total. While burning has not been removed as a viable slash disposal method, additional constraints have been placed on its use. The remaining categories of compliance actions were miscellaneous at 8.5%, unauthorized access at 7.2% and unauthorized or avoidable impacts to agricultural resources was 6.2%, of the total respectively.

## DISCUSSION

### The need for and unauthorized taking of extra workspace

Adverse impacts to the human and natural environment are an unavoidable consequence of gas pipeline construction. The disruptive nature of certain phases of pipeline construction (clearing, grading, trenching etc.) dictates that these activities must be confined to the approved ROW. After examining the data detailed earlier and FCU staff field logs, we were able to conclude rather quickly that an inordinate amount of staff time was spent addressing the company's or contractor's need to acquire and use extra workspace, or detailing its unauthorized use.

There are numerous reasons why a contractor or company would need more temporary work room. The Department recognized this and instituted the minor change process in an effort to ensure that modifications of construction plans could be made quickly. Despite the best efforts of the Department, contractors and company personnel cleared woods, graded lands, stockpiled logs, slash and topsoil on lands outside of the approved ROW. These actions led to avoidable losses of, or unnecessary damage to, adjacent vegetation, topsoil, soil productivity, adjacent land uses as well as crops.

The Department's goal is to get companies to use the minimum amount of resources necessary to safely, economically and efficiently construct gas pipeline facilities in an environmentally compatible manner. To accomplish this goal, more care must be taken by applicants in the planning stages to request and acquire sufficient temporary ROW for their needs. Regulators and other parties must also develop "realistic" expectations about the minimum width of ROW necessary for construction of gas lines of a given size. The diameter of the pipeline to be built, the severity of terrain to be crossed, the size and type of equipment to be used for installation and the amount of ROW used in construction of similar pipeline projects, are all factors that should be considered before a final determination of ROW dimensions is made.

Recognizing that there may be constraints (physical, socio-economic and political) on the width of ROW a company can acquire, these must be balanced against the physical practicalities of construction. Very often, this balance can only be reached after the needs of construction have been thoroughly assessed in the field. To address the need for added flexibility, Staff and the Department have streamlined the minor change process in an attempt to ensure that companies constructing gas lines under Article VII in New York State, can make modifications in a reasonable time frame so as to discourage unauthorized off-ROW activities and expedite construction. Department staff has also changed the manner in which pipeline projects are reviewed before approval. Since 1995, FCU staff have been brought into the application review process earlier and have provided input on workspace needs before the initiation of construction.

### Stream crossings

The largest area of EM&CP non-compliance involved pipeline construction across streams. The majority of these incidents dealt with failure to control trench spoil, failure to comply with construction time limits or the improper use or installation of erosion and sediment control devices. In 21 instances, company or contractor personnel failed to prevent saturated trench spoil from reentering streams thereby, adversely affecting water quality downstream. Company and contractor personnel also had trouble maintaining erosion and sediment control devices on slopes adjacent to streams. Failure to install or maintain ditch plugs, trench breakers and other erosion and sediment control devices, led to 15 documented instances of sediment laden water entering streams.

In an attempt to limit impacts on water quality, the Department of Public Service worked with the New York State Department of Environmental Conservation (DEC) to develop project-specific construction conditions. This usually involved the institution of time limits or "windows", periods during the year where in-stream work would be allowed. Also, the Commission instituted time frames on in-stream construction which would require that, once initiated, in-stream work had to be concluded within 24–48 hours. Eighteen times, in-stream work was not completed within prescribed time limits. An examination of field logs showed that often, company or contractor personnel were not prepared to finish a stream crossing once initiated and usually initiated the crossing too late in the work day.

To address this, staff is currently modifying its own in-house construction standards which will detail what the Department considers best construction practices during stream crossings. These practices include methods for "wet" and "dry" stream crossings, devices and techniques for handling supersaturated trench spoil and others. In addition FCU staff are working with companies, other agencies and other department staff to develop job and site- specific stream crossing conditions before construction begins. All major stream crossings are reviewed in the field, often in pre-planning stages to gain FCU staff input prior to approval of sensitive crossings.

### Wetlands

The primary problem which occurred when crossing wetlands was the mixing of soil layers and the inability of contractor and company personnel to keep excavated topsoil separated from other soils layers. This problem is often related to the need for additional workspace or other project constraints which may have limited the amount of temporary ROW available in wetlands. While recognizing the fragile nature of many wetland environments may lead some regulators and environmental organizations to limit the ROW width in wetlands, the realities of working with saturated or super-saturated soils must likewise be recognized and dealt with in a realistic and appropriate manner.

Due to the value of wetland resources, Department Staff is currently revising its in-house construction standards and practices to develop better crossing techniques and workspace requirements. Additionally, as with stream crossings, FCU staff are providing pre-construction review and recommendations on wetland crossings to Department and company personnel. This includes reviewing proposed crossings before they are submitted to the Commission for approval and offering alternative crossing methods or recommendations on work space requirements. For example, staff may, based upon observation of crossings in similar wetlands, recommend that a particular resource be crossed via directional drilling or traditional push bore as opposed to open-cut.

## CONCLUSIONS

Regulators, gas transmission companies, contractors, environmental organizations, landowners and all other interested parties, must work together to equitably assess the ROW needs prior to the approval of projects or the initiation of their construction. Practical experience and on-site conditions must be weighed equally with environmental, socio-economic and political concerns when the width of proposed ROW is considered. All parties involved in pipeline construction should continually reassess construction standards and practices under the pragmatic light of practical experience and empirical research.

Stream and wetland crossings often represent the most difficult features to be crossed by any pipeline project. All resources and experience should be applied to planning their crossings prior to the initiation of construction. After construction commences however, regulators must be flexible enough to allow for timely modification of approved plans based upon on-site, in-field conditions. Regulators must have sufficient, experienced personnel in the field during pipeline construction to quickly and efficiently review these changes.

## ACKNOWLEDGEMENTS

Technical support was provided for this paper by Linda Demer's and the staff of the Office of Information Services at the New York State, Department of Public Service. Additional support was also rendered by Wayne Fuhrman, Charles Dickson and John Maio of the Office of Accounting and Finance, New York State Department of Public Service.

## REFERENCES

INGAA Foundation. 1996. Roundtable on pipeline construction workspace requirements. 24–26 September.

McAllister, W.W., ed. Pipeline Rules of Thumb Handbook, Second Edition. Gulf Publishing.

---

## *BIOGRAPHICAL SKETCH*

***David D. Macks***

*New York State Department of Public Service, 3 Empire State Plaza, Albany, NY 12223, USA*

David Macks graduated from the New York State Ranger School in Wanakena, New York, in 1976 with an A.A.S. in Forestry. He served as a Sergeant in the US Army Combat Engineers for three years before returning to school in 1979. He graduated from College of Environmental Science and Forestry at Syracuse with a B.S. in Forestry/Resource Management in December 1981. He has worked as a Transmission Facilities Analyst for the New York State Department of Public Service since 1992.

***David Morrell***

*New York State Department of Public Service, 3 Empire State Plaza, Albany, NY 12223, USA*

David Morrell graduated with an A.A.S. in Land Management from the State University of New York at Cobleskill in 1981. He received his B.S. in Forest Management from West Virginia University in 1984. He has worked with the New York State Department of Public Service as a Transmission Facilities Analyst since 1991. He enjoys outdoor pursuits in his spare time.

***John Strub***
*New York State Department of Public Service, 3 Empire State Plaza, Albany, NY 12223, USA*

John Strub graduated from the New York State College of Environmental Science and Forestry at Syracuse University in 1971, with a B.S. in Forestry/Resource Management. He worked for eighteen years with private engineering and tree trimming companies before joining the Department of Public Service as a Transmission Facilities Analyst in 1991. His interests include church and family activities and commercial forestry.

# We, They, Us: A Case Study of Environmental Compliance. The Tuscarora Gas Transmission Project

John A. McCullough

In 1995, the Tuscarora Gas Transmission Company (a partnership of the Tuscarora Gas Pipeline Company, a wholly-owned affiliate of Sierra Pacific Resources, and TCPL Tuscarora, a wholly-owned affiliate of TransCanada PipeLines, Ltd.) constructed the 366 km (229-mile) Tuscarora Natural Gas Pipeline Project. The construction of this pipeline set a new standard for environmental compliance programs in the pipeline industry, accomplished amidst a myriad of EIR/EIS mitigation measures, permit conditions, environmental requirements and plans, and a cadre of agency field monitors. The program demonstrated that even a complex project can be constructed successfully and in compliance with the requirements by establishing a strong plan with innovative techniques, and a solid working relationship between the project proponent and federal and state agencies. Tuscarora's compliance team was staffed by veterans who were well-versed in pipeline compliance programs, and in achieving this success they acknowledge that the Tuscarora Project was the most difficult in their combined years of compliance experience. Their observations and perceptions are incorporated into this review of organization, experience, training, communication, and results.

*Keywords*: Tuscarora, KEA Environmental, environmental compliance, training, computer reports, inspection, monitoring, communication, pipeline

## INTRODUCTION

The Tuscarora Natural Gas Pipeline Project set a new standard for environmental compliance programs in the pipeline industry and was accomplished amidst a myriad of EIR/EIS mitigation measures, permit conditions, environmental requirements and plans, and a cadre of agency field monitors. The program demonstrated that even a complex project could be constructed successfully and in compliance with the requirements by establishing a strong plan and a solid working relationship between the project proponent and federal and state agencies. Tuscarora's compliance team was staffed by veterans who were well-versed in pipeline compliance programs, and in achieving this success, they acknowledge that the Tuscarora Project was the most difficult in their combined years of compliance experience. Their observations and perceptions are incorporated into this review of organization, experience, training, communication, and results.

## PROJECT DESCRIPTION — FACTS AND STATS

In 1995, the Tuscarora Gas Transmission Company (a partnership of the Tuscarora Gas Pipeline Company, a wholly-owned affiliate of Sierra Pacific Resources, and TCPL Tuscarora, a wholly-owned affiliate of TransCanada PipeLines, Ltd.) constructed a 51.9 cm (20-in), 366 km (229-mile) pipeline from Oregon through northeastern California and terminating at Sparks, Nevada, east of Reno. The effort was divided into two construction spreads: Spread 1, consisted of the first 162 km (100 miles), running south from Oregon to Madeline, California; and Spread 2 contained the final 208 km (130 miles) to Sparks, Nevada.

The project was completed successfully and dealt with of a multitude of environmental issues requiring careful planning, commitment, and coordination with agencies. The primary federal and state agencies included Bureau of Land Management (BLM), the Forest Service (USFS), the California Department of Fish and

**Table 1. Project statistics**

| Significant statistics | |
|---|---|
| Wetlands crossed | 48 ac |
| Waters of the US crossed | 216 |
| Perennial waters crossed | 10 |
| Special status plant locations crossed | 124 |
| Special status wildlife construction windows* crossed | 70 |
| Cultural Resource sites crossed | 128 |
| EIR/S Mitigation Measures | 223 |
| Special Mitigation Plans and Details | >100 |
| Permits | >90 |
| Construction personnel at peak | ≅1000 |
| Agency Environmental Monitors at peak | 15 |
| Tuscarora Environmental Inspectors at peak | 8 |

*Periods when construction was prohibited or restricted.

**Table 2. The bottom lines**

| | |
|---|---|
| Acres of disturbance | <2500 |
| Tuscarora and Agency individual inspection events | 6871 |
| Tuscarora or Agency issued Noncompliance Reports | 154 |
| Incidents significantly damaging natural resources | 0 |

Game (CDFG), the California State Lands Commission (SLC), and the Federal Energy Regulatory Commission (FERC). The EIR/EIS mitigation measures (223), special mitigation plans and details (over 100), over 90 permits, and up to 15 agency field monitors provided a unique challenge for Tuscarora and its contractors. Table 1 summarizes the significant statistics and Table 2 gives a sketch of results.

Because of the extensive requirements and the expected, continuous presence of agency field monitors, Tuscarora brought together a team of experienced environmental consultants. Their goal was to establish and implement an environmental compliance program to assure that the Tuscarora Pipeline was constructed within all commitments.

## THE PROGRAM

The construction compliance program, designed and implemented by KEA Environmental and Essex Environmental, emphasized a commitment to protection of resources and shared responsibilities between the construction and environmental staff and agency monitors sustained by open and timely communications.

Support from an organization's upper management is the only way a compliance program can succeed and Tuscarora's commitment to successful compliance established the goals from the very beginning. Strict guidelines were developed to ensure that experienced individuals filled the key environmental staffing roles. To achieve Tuscarora commitments, a supportive management group, a staff composed of professionals, a training program, and a method of communication provided the framework for the compliance program. This framework and the project results are discussed in the following sections.

### Organization and support

Knowing that an effective compliance program requires more than just placing individual inspectors in the field, Tuscarora established an environmental management organization in the Reno project office to work directly and side by side with the Project, Lands and Construction Managers. The positions, a Field Supervisor and a Field Coordinator, formed direct links between their environmental staff on the ground and upper project management. These connections ensured that environmental issues were treated equally and expeditiously along with construction and overall project demands. Figure 1 shows the Tuscarora Project organization and support.

The Field Supervisor, as facilitator and liaison, was directly responsible for all compliance activities and reported directly to the Project Manager. As an equal participant on the Reno project management team, he was able to bring field problems immediately to managers for resolution whenever necessary. In addition, he acted as a conduit to project management for the many agencies with monitors in the field.

The Field Coordinator provided coordination to the field staff, maintaining records of activities and furnishing information to Tuscarora and agency personnel upon request. He supported the field and project management as planner, obtaining permits and approvals for new, unanticipated field requirements.

The unanimous single factor that contributed to the success of the program, as reported by the environmental field staff, was the absolute and continuous support they received from the management team (project, construction and environmental). The environmental component was always placed on an equal level of concern with construction issues.

*Reasons for success*

- Partnership between project, construction, and environmental management
- Credo: "Identify the problem, fix it quickly; get ready for the next one"
- Environmental team was given an equal presence with Construction at contractor discussions

*Improvement areas*

- More time on the ground by Field Supervisor (more than the 30% actual)
- More administrative support staff needed in the project office, allowing the Field Supervisor to spend more time in the field

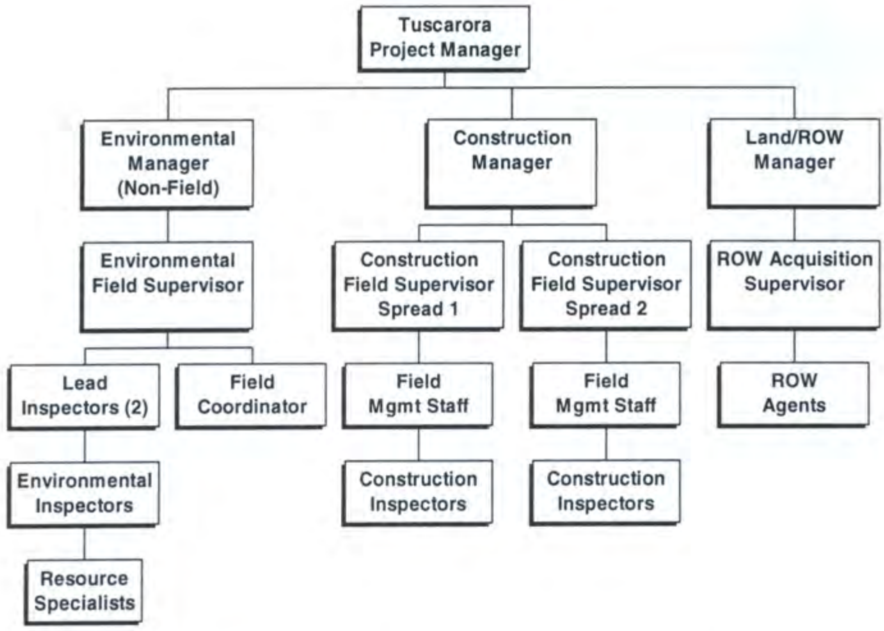



Fig. 1. The Tuscarora Project organization and support.

## Environmental staff

The magnitude of environmental issues and requirements contained in the multitude of mitigation measures, permits, plans and mitigation details (shown on Table 1) became the first part of an equation to be solved. Added to the formula was a full-time agency field presence represented by FERC, USFS, BLM, and CDFG, which consisted of 15 or more monitors who did not have pipeline experience. Typically, pipeline projects require fewer full-time agency field representatives. The solution to this equation was simple. Tuscarora needed a qualified field staff of veteran pipeline environmental inspectors that required little training and who could immediately begin to ensure implementation of the Tuscarora commitments.

A team of experienced and respected professional environmental inspectors was hired for the construction effort. The strictest requirement for becoming a Tuscarora Environmental Inspector (TEI) was a minimum of two years of field experience in reclamation, erosion control, *and environmental compliance or monitoring of pipeline work.* Initially, six inspectors were assigned, three to each spread; however, an additional inspector was added to each spread in September in response to increased construction activity.

In addition to the TEIs, the field team included seven Resource Specialists in non-inspection roles: two soil scientists, two biologists, and three archaeologists. These individuals were involved in flagging and fencing resources and monitoring specific locations when necessary.

During construction, an inspector typically worked 12–14 hours per day, six days per week. During that time, the primary role was to inspect the contractor's activities to ensure compliance. Often the inspector was required to take time away from normal inspection duties to share experience and knowledge or negotiate conflicting opinions with the inexperienced agency monitors. The biggest challenge was to work *with* the monitors to develop a problem solving approach to getting the pipeline built while staying in compliance.

Together, the Tuscarora inspection team and the collection of agency monitors became a formidable group in the field (Fig. 2), whose primary focus was to identify problems while they were still small, and resolve them before they could develop into significant situations. Although there was disparity at times between some of the Tuscarora and agency environmental staff, the joint compliance program was recognized by all parties as a success.

*Reasons for success*

- Support by Tuscarora and contractor management levels
- Use of highly qualified and experienced environmental inspectors
- Significant agency presence, even though they were inexperienced

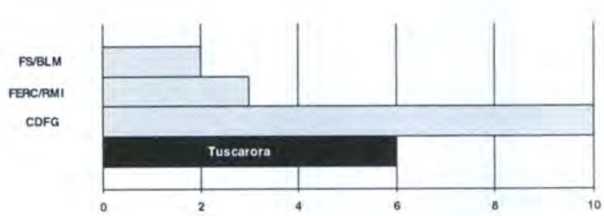



Fig. 2. Agency monitors and Tuscarora inspectors. FERC/ RMI = field consultant for FERC.

*Improvement areas*
- Use fewer but qualified agency monitors
- Work as a team; moderate adversarial viewpoint on both sides
- Report the facts; don't editorialize; improve record keeping on field reports
- Use fewer, formalized details and specifications to allow more field decisions to fit local conditions
- Solve problems at lower level in the field; if solution cannot be quick, then kick the problem upstairs

## Environmental training

Tuscarora implemented a multifaceted training program geared toward "partnering", a far-reaching concept where the company and agencies would join together as a team to accomplish a successful project, i.e. in compliance with environmental commitments. Training consisted of three levels: management, worker, and on going (tailgate sessions).

*Management training*
Initial management training consisted of a two-day session by Essex Environmental that included representatives of agency management and monitors, Tuscarora management and inspectors, and contractor field managers and foremen. The program was designed to give all parties an opportunity to speak, share ideas and viewpoints, hear lectures, and participate with interactive exercises designed to promote learning and partnering. Interaction between the groups was educational and social, and contributed the first step toward modifying any preconceived "we–they" attitudes.

Since most agency representatives and monitors were being exposed to pipeline construction for the first time, the program focused on real examples of construction and environmental conflicts. This included typical compliance issues and preventative measures; what to watch for in the field; identification of successful implementation; and early indicators of compliance concerns. An important element of this session was the delivery of the compliance requirements to company, contractor, and agency personnel at the same time.

While perfection rarely occurs in reality, Tuscarora expected construction activities in compliance with the commitments made for permit requirements, plans, and mitigation measures. This message was direct and clearly presented at the management training session. A pre-project *estimated* level of compliance–noncompliance statistics (Table 3) was shown to the agencies as realistic example of what they probably would experience on the Tuscarora Project.

**Table 3. Estimated inspection results**

| | Inspections (%) |
|---|---|
| Inspections In Compliance | |
| Acceptable | 80 |
| Minor problems | 10 |
| Inspections in Non-Compliance | |
| Violation | 5 |
| Repeated Violation | 3 |
| Serious Violation | 1 |
| Emergency (may not be noncompliance) | <1 |
| Total inspections | 100% |

*Worker training*
All workers (and visitors) were required to attend a brief training session prior to entering the field. Conducted by a TEI, this 30-minute session was directed toward the contractor's personnel, who would ultimately be the lowest level staff required to follow the rules. Based upon responses heard throughout the construction period, the workers heard the message for the most part and did their best to work within the parameters required.

*Tailgate sessions (on-going training)*
At times during construction, the TEIs provided tailgate (special field training) sessions for the workers to highlight or emphasize upcoming natural resources or conditions requiring special attention. Additionally, repeated instances of non-compliance, i.e., soil separation, erosion control, and oil spills, necessitated tailgate sessions to reinforce the project requirements. This extra training proved to refocus the workers when necessary. After these sessions, repeated non-compliance's diminished significantly.

*Reasons for success*
- Tuscarora made strong environmental commitments
- Training program delivered the message
- Pipeline contractors got the message and tried to stay within compliance

*Improvement areas*
- Keep the partnering concept; de-emphasize the literal idea
- Add daily inspection report writing to the program
- Develop joint understanding of different levels of acceptability

## Communication and record keeping

With 1,000 construction workers, 368 km (230 miles) of pipeline, and over 20 environmental inspectors and agency monitors, communication and record keeping became an integral thread for the environmental compliance program. The Tuscarora Project used cellular phones and radios for primary communication while the compliance program staff and some of the agencies also used a network of computers to record, provide, and exchange information.

*Communication*

On each spread, radios were used to communicate between individuals in the field and to the field offices. Radios proved to be an effective method of contact when within repeater range. The TEIs and agency monitors were on the same frequency as the Tuscarora construction management personnel, and the mainline contractors had their own frequency. Cellular phones were also available for most groups, and were used regularly when radio service was unavailable or privacy was required. The phone was the only method of communication between the Reno project office and the field, while the two field offices maintained radio links with their respective spread personnel.

TEIs used both devices equally and neither was preferred. Although dead zones existed for both radio and cellular phones, the areas did not seem to cause a major obstacle to communication.

*Record keeping*

The TEIs and agency monitors were required to record their inspection and monitoring activities on a daily basis. Tuscarora, CDFG, and the FERC monitors used a computer network of laptops and base servers to record, submit, and exchange their daily recordings of inspection and monitoring activities. The Forest Service and BLM monitors did not use the network. PipeTrak, a computer database, was jointly designed and implemented by the agencies and Tuscarora to keep track of inspection and monitoring records (Fig. 3). TEIs submitted their daily reports by modem to a computer server in the Reno project office, while the agencies sent their daily records to a server at the CDFG in Redding, California. Every morning each server would fax a newsletter containing the previous day's Tuscarora inspection and agency monitoring records to individuals on a project distribution list.

PipeTrak proved to be an invaluable record system, as well as a communication tool, although it increased work time due to data entry requirements. Because of dust, high daytime temperatures, and to avoid losing inspection time, the TEIs kept written notes of their inspections and entered their daily records to the computer after the day's field activities had been completed.

*Reasons for success*

- Multiple communications systems were available
- PipeTrak was excellent for record keeping; data proved useful in tracking compliance and non-compliance
- PipeTrak was excellent for sharing information

*Improvement areas*

- Train agency monitors in report writing
- Set up separate training for use of PipeTrak
- Re-examine when data needs to be entered into computer (after hours adds to the work day)
- Use single server and newsletter for all parties instead of separate systems

## SUMMARY OF RESULTS

Did the concept of "partnering" work? Yes and no. The contractors and their workers seemed to recognize Tuscarora's commitment to the environment and, in that sense, entered into a partnership to achieve a successful project. Both contractors tried to stay in line

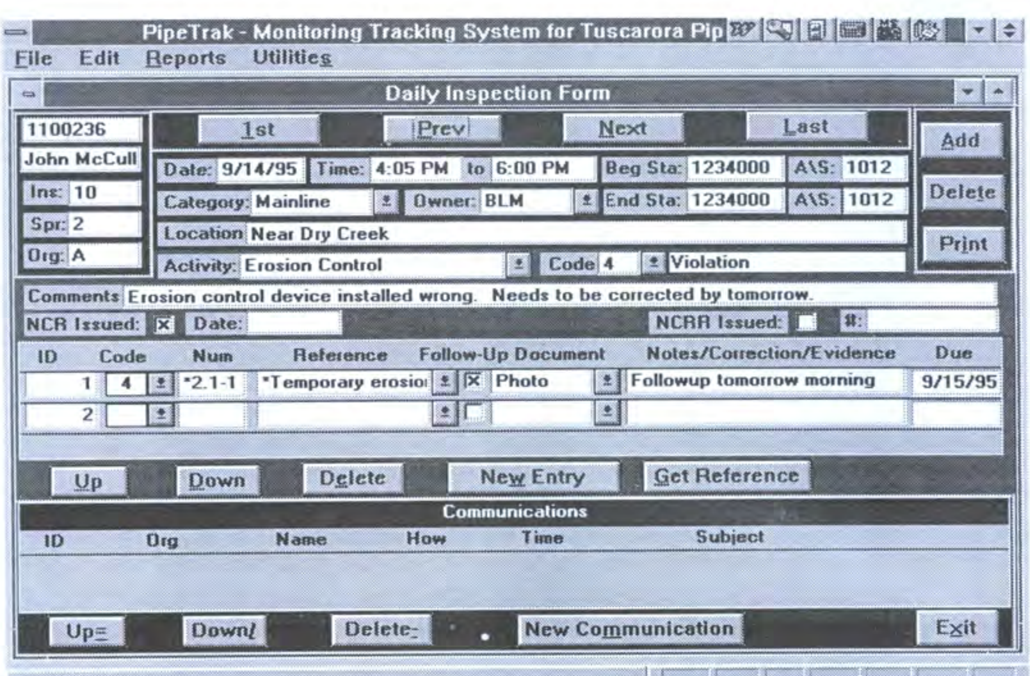



Fig. 3. PipeTrak laptop screen.

with project requirements most of the time. The majority of agency monitors worked in a positive way to resolve problems using a team approach, while some remained continuously adversarial. Nevertheless, the concept of partnering did help to open doors for communication and understanding. Those who chose to walk through, did.

The use of PipeTrak for record keeping allowed analysis of all recorded Tuscarora inspections, as well as CDFG (agency) and FERC (agency) monitoring events. This summary evaluates the 6,871 records received from the three organizations.

Figure 4 shows the distribution of total inspection and monitoring records between the three groups using the PipeTrak record system. Typically, an analysis would include average records per person each day, but the variation in days worked per week and the number of individuals working each day made that type of comparison invalid. Nevertheless, the groups can be compared as shown.

Previously, in the section of this discussion on Environmental Training, Table 3 showed Tuscarora's estimated inspection category distribution, which is repeated in Fig. 5 and labeled as "May Estimate". The graph section labeled "December Actual" shows the results of the inspection/monitoring program at the end of construction. Table 4 shows the difference between the estimated and actual results.

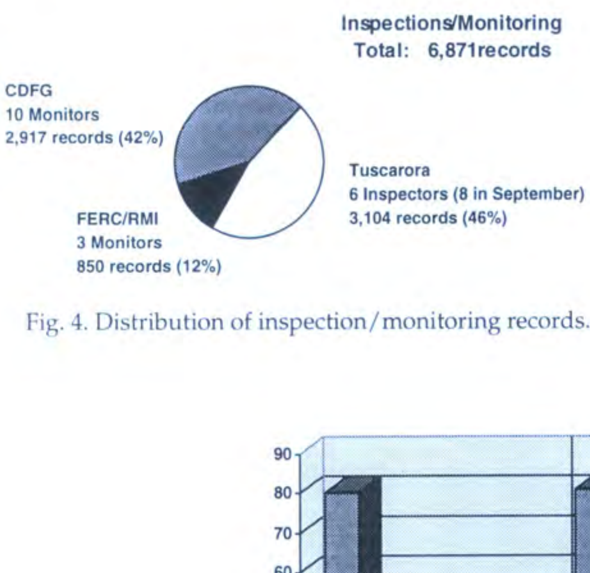



Fig. 4. Distribution of inspection/monitoring records.

**Table 4. Inspection categories**

| Inspection Category (6,871 records) | Estimated % | Actual % | Difference % |
|---|---|---|---|
| In Compliance | | | |
| Acceptable | 80 | 80.7 | +0.7 |
| Minor Problem | 10 | 15 | +5 |
| Non-Compliance | | | |
| Violation | 5 | 3.8 | −1.2 |
| Repeated Violation | 3 | 0.3 | −2.7 |
| Serious Violation | 1 | 0.1 | −0.9 |
| Emergency (compliance or non-compliance) | <1 | 0.03 | −0.97 |
| Total Inspections | | | 100 |

The actual environmental inspection and monitoring records kept by Tuscarora and the agencies demonstrate that Tuscarora significantly improved upon its estimate in compliance goals. Almost 96 percent of recorded inspection/monitoring records were shown as Acceptable or as Minor Problems. The training objective of identifying and correcting problems before they became violations was accomplished.

## Non-Compliance Reports

The remaining 4% of inspection/monitoring records (288), recorded as non-compliances, resulted in 154 Non-Compliance Reports (NCRs) issued to the contractors by Tuscarora, RMI or CDFG, or all three. The difference between the number of recorded events and the issued NCRs was a procedural problem that actually inflated the non-compliance records. Often, all three groups would record the same non-compliance, but only one group would issue the NCR.

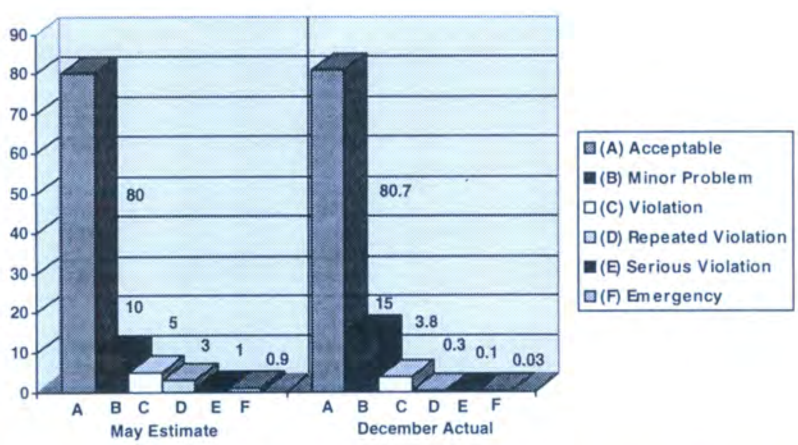



Fig. 5. Levels of compliance. Preconstruction estimates – postconstruction actuals.

Another procedural problem occurred when NCRs were duplicated for the same event, e.g., one issued by Tuscarora and one or more from the other groups. This inflated the number of NCRs. However, accepting the NCR record (154) instead of the inspection/monitoring records (288) as the basis for determining project non-compliances, the compliance record improves to 98% of the total inspection/monitoring events (6,871).

### Five most common Non-Compliance Report references

Of the total NCRs (154) issued by Tuscarora and the agencies, 106 reports (68%) referenced the five project requirement categories listed in Table 5 as the most prevalent areas of non-compliance. The top two were Topsoil Segregation and Not Following Project Plans, in that order. The five categories are discussed in the following sections.

*#1 — Topsoil Segregation (29 NCRs)*

EIR/EIS Mitigation Measure 2.1-4 required separation of topsoil from subsoil which would usually need to occur during grading and trenching activities. Adding complexity to the requirement, Tuscarora committed, in its Environmental Mitigation and Reclamation Plan, that the separation would be 0.9 m (3 ft). This was a commitment that proved difficult to achieve, thus becoming the most common non-compliance. In fact, a number of records in the Reference #2 category, Did Not Follow Plan, also include this non-compliance.

Because of the number of violations of the 0.9-m (3-ft) separation commitment, a Field Variance procedure was established where Tuscarora would submit a request to the agency field monitors to change a requirement that did not fit field conditions or, as in this case, was impractical. Tuscarora submitted a variance, which contained a Soil Segregation Plan that replaced the 3-ft requirement with more accomplishable procedures for soil separation. As a result, compliance under this type of situation improved significantly.

*#2 — Did Not Follow Plan (27 NCRs)*

Table 1 showed that more than 100 special mitigation plans and construction details contributed a major number of the construction requirements. A great many of these duplicated one or more of the EIR/EIS mitigation measure requirements. As a result, the TEIs and agency monitors had a choice of references to select to document a non-compliance. Table 5 shows an unusual distribution for this reference category: it was used in only 2 NCRs on Spread 1 but in 25 on Spread 2. However, sixteen of the NCRs using this reference on Spread 2 actually belong in Reference #1, #3, #4, or #5. The Spread 2 TEIs and monitors apparently preferred to use the Did Not Follow Plan rather than look up the correct mitigation measure.

*#3 — Hazardous Materials Spill (22 NCRs)*

This type of non-compliance increased in frequency from the middle of September to the middle of October (77%), a period when the contractors equipment began to stress from working for two months in the rocky conditions. Minor oil spills/drips became more prevalent. In response, the TEIs implemented an equipment audit that was performed weekly requiring faulty, leaking equipment to be repaired immediately or be removed from the ROW. Once the audit was in place, the frequency of oil spill non-compliances decreased significantly, dropping to only four after 15 October.

*#4 — Temporary Erosion Control (15 NCRs)*

This type of non-compliance seemed to occur for two reasons: (1) the way the erosion control structure was installed (Did Not Follow Plan) or (2) the lack of maintenance (cattle often ate or destroyed the erosion control structure). Project details showed specific ways to install the structures, e.g., angle of stake, type of stake, etc. Any deviation (i.e., a loose stake; a pulled staple) resulted in a violation. Cattle would often eat the straw bales and knock down the silt fencing. This was recorded as a violation if it wasn't reinstalled by the following day. Table 5 shows an interesting distribution of NCRs for this issue: Spread 1 had 13 and Spread 2 had 2. One agency monitor on Spread 1 seemed to

**Table 5. Five most common Non-Compliances**

| Rank | Issue | Spread One | | | | Spread Two | | | | Total NCRs |
|---|---|---|---|---|---|---|---|---|---|---|
| | | TGTC | RMI | CDFG | Subtotal | TGTC | RMI | CDFG | Subtotal | |
| 1 | Topsoil Segregation | 7 | 6 | 2 | 15 | 3 | 7 | 4 | 14 | 29 |
| 2 | Did Not Follow Plan | 0 | 2 | 0 | 2 | 5 | 9 | 11 | 25 | 27 |
| 3 | Hazardous Mat Spill | 3 | 7 | 0 | 10 | 1 | 7 | 4 | 12 | 22 |
| 4 | Temp Erosion Control | 3 | 7 | 3 | 13 | 1 | 1 | 0 | 2 | 15 |
| 5 | Activity Off-Row | 4 | 0 | 0 | 4 | 6 | 1 | 2 | 9 | 13 |
| | Total NCRs | 17 | 22 | 5 | 44 | 16 | 24 | 21 | 62 | 106 |

specialize in this type of non-compliance, writing 50% of the total temporary erosion control NCRs. Spread 2 inspectors and monitors used Reference #2 instead of #4.

*#5 — Activity Off-Right-OF-Way (13 NCRs)*
All participants in the Tuscarora Project were required to stay within the approved right-of-way (ROW) which varied from 65 to 100 feet. Most of these non-compliances were recorded for topsoil or trench spoil piles drifting off-ROW by several inches or feet. Several NCRs were issued when equipment left the ROW area. Spread 2 equipment operators seemed to have the most problem in complying with this requirement; five operators were discharged early in the project for Reference #5 non-compliances.

### Resolution of Non-Compliance Reports

When an NCR was issued by TEIs or agency monitors, it remained "on the books" and required resolution, e.g. cleanup, re-training, which was then documented by a Non-Compliance Resolution Report (NCRR). NCRRs reconciled all 154 NCRs and the record was completed.

## VALIDITY OF MITIGATION MEASURES AND THEIR CONTRIBUTION TO NON-COMPLIANCE

Often inappropriate wording contained in mitigation measures or plans can lead or contribute to non-compliances. A number of the mitigation measures, whether contained in the EIR/EIS or in Tuscarora-written plans and details, were found to be inapplicable for field conditions or were written with such extremes that field application proved more excessive than necessary to protect the environment. Two examples are discussed.

First, soil segregation difficulties, reviewed earlier, resulted from a commitment written by Tuscarora in its Environmental Mitigation and Reclamation Plan to maintain a 0.9 m (3-ft) separation between topsoil and subsoil piles. This detail proved to be impractical and often impossible to achieve when working in a narrowed right-of-way, cut-slopes, or rocky conditions. More achievable procedures established in preconstruction planning would have accomplished the goal of topsoil segregation and avoided the difficulties associated with the 0.9 m (3-ft) construction detail, resulting in more compliance situations.

Second, in a project region considered to be arid-semiarid, a multitude of erosion control mitigation measures contained in numerous plans, permits, and other project documents proved to be costly overkill. Precipitation in the area ranges from 8 to 16 inches annually with a predominance in the form of snow during the non-construction winter season. The EIR/EIS failed to consider the climate of the project region, and incorporated major erosion control requirements during the dry season when precipitation is low to non-existent. On the Tuscarora Project, it was not unusual to look across the flat desert and see erosion control structures consisting of strawbales and silt fences in dry, minor intermittent drainages and ephemeral swales that rarely saw water in the summer season. While summer thunderstorms were known to bring bursts of heavy rains that can result in flashfloods, the erosion control structures designed for normal precipitation would never have withstood the force of a flashflood, regardless of the time of year. No project documents tried to balance the dry construction period (it never rained) with practical erosion control methods and application. As a result, many agency monitors relied on the written requirements that overemphasized the need and locations for erosion control, and focused on non-compliances described previously. A risk assessment surely would have shown that the potential for major erosion impacts during summer construction was far less than the magnitude of erosion control requirements implied.

Finally, the sources of many mitigation measures and requirements frequently come from previous documents, permits, or so-called Best Management Practices. As so often is the case, the writers, whether they were agencies, Tuscarora, or consultants, simply perpetuated previously written concepts and practices without consideration of the actual conditions expected to be encountered. The field variance procedure used by Tuscarora and the agencies was an attempt to reconcile these differences after the project was under way. However, project requirements and commitments are normally developed prior to construction. They should be written by those who have had field experience, applying that experience to sensible, flexible requirements. Mitigation measures and requirements should never be "boiler-plate" as this can contribute to meaningless non-compliance events. They should always be adjusted and fine-tuned to best fit a specific project and project area.

## CONCLUSION

The Tuscarora Project was a challenge for everyone involved including project, construction, and environmental staff, and the federal and state agency representatives who were directly involved with the day to day development of this project. Unquestionably, it was a difficult and stressful experience for most. For many of us, we began the project thinking, as veterans, as professionals, that we had all the answers. We and They learned that you can never stop learning. We and They learned that a project can succeed with environmental compliance when the project proponent and the jurisdictional agencies work together as a team.

Compliance happens when We and They become... Us.

## ACKNOWLEDGEMENTS

This paper is dedicated to Greg Galbraith and Terry Wolverton, Tuscarora Gas Transmission Company, for their commitment, and to Rod Heller, KEA Environmental, for his support.

## REFERENCES

KEA Environmental. 1996. Tuscarora Gas Transmission Project, Environmental Compliance Program, Construction Phase Closure Report. Sacramento, California.

## *BIOGRAPHICAL SKETCH*

***John A. McCullough***

*KEA Environmental, 455 University Avenue, Suite 370, Sacramento, CA 95825, USA*

John McCullough has a BA degree in Geography from California State University at Hayward, and in 1995 completed a 23-year career in environmental planning with the Pacific Gas & Electric Company and the Pacific Gas Transmission Company. He joined KEA Environmental as a Senior Associate/Senior Project Manager, specializing in the development and implementation of environmental compliance programs.

# Environmental Comparison of Pipelines in Canada and the U.S.

**Dean F. Mutrie and Karl B. Gilmore**

Although the environmental issues involved in pipeline construction are relatively similar in Canada and the U.S., the regulatory approaches are substantially different. Based on the author's experience with environmental permitting of pipelines across Canada and the western U.S., this paper compares pipelines on a federal (NEB vs FERC) and provincial/state (Alberta vs Montana) basis. The paper reviews current practice involving regulatory requirements, environmental impact assessment as well as environmental mitigation planning and construction practices in the respective jurisdictions. Similarities and differences are highlighted regarding treatment of threatened and endangered species, cultural resources, wetlands, water crossings, topsoil conservation, environmental inspection and training, compliance enforcement and agency compensation. The paper concludes that there is a high degree of environmental protection achieved on pipeline projects in both countries but that the regulatory process is becoming increasingly complicated, particularly in Canada where the recently proclaimed *Canadian Environmental Assessment Act* and other new federal and provincial guidelines and legislation have introduced uncertainty. Lessons which can be learned from each country are identified.

*Keywords*: Pipelines, environment, Canada, United States, permitting, assessment, mitigation, construction, inspection

## INTRODUCTION

Environmental regulations have been increasingly applied to pipeline projects in both Canada and the United States (U.S.) for nearly 30 years. Despite the similarity of environmental issues and pipeline construction practices in the neighboring countries, the regulatory approaches which have evolved are substantially different. One similarity is that environmental regulation never remains constant — it is a continually evolving series of often confusing and occasionally conflicting legal directives and guidelines driven by a groundswell of popular support for protecting the environment. This paper attempts to take a 1996 snapshot of the regulatory maze and environmental mitigation measures currently in use on both sides of the border. There are important lessons to be learned from a comparative examination of environmental regulations and pipeline practices in the two countries.

The opinions expressed in this paper are based on the personal experience and observations of the authors during their work as environmental consultants on more than 1,000 pipeline projects across Canada and on several projects in the U.S. over the past 21 years.

## REGULATORY BACKGROUND

### Federal jurisdiction

Prior to looking specifically at environmental matters, it is first necessary to examine the overall regulatory process for permitting major pipelines in the two countries. Table 1 outlines some of the key similarities and differences for major interprovincial or interstate gas pipelines. In both countries, the applicant seeks a Certificate of Public Convenience and Necessity. In Canada the Certificate is issued by the National Energy Board (NEB), whereas in the U.S. it is issued by the Federal Energy Regulatory Commission (FERC). The NEB has always administered oil, gas and liquids pipelines, and recently has extended its jurisdiction to also include non-energy commodity (e.g., $CO_2$) pipelines as well. Although oil pipelines are identical to gas lines in terms of construction techniques and environmental

**Table 1. Regulatory comparison of major interprovincial/interstate gas pipelines in Canada/U.S.**

| | Parameter | Canada | U.S. |
|---|---|---|---|
| 1. | Legal Authority | Certificate of Public Convenience and Necessity under Section 52 of the *National Energy Board Act*. | Certificate of Public Convenience and Necessity under Section 7 of the *Natural Gas Act*. |
| 2. | Authorizing Agency | National Energy Board (NEB), Calgary, Alberta | Federal Energy Regulatory Commission (FERC), Washington, D.C. |
| 3. | Other Federal Agencies | Canadian Environmental Assessment Agency (CEA Agency)<br>Environment Canada, Fisheries and Oceans (DFO)<br>Canadian Wildlife Service<br>Agriculture Canada<br>Coast Guard<br>Indian and Northern Affairs Canada (INAC) | Bureau of Land Management (BLM)<br>Bureau of Reclamation (BOR)<br>U.S. Forest Service (FS)<br>U.S. Fish and Wildlife Service (FWS)<br>U.S. Army Corps of Engineers (COE)<br>Environmental Protection Agency (EPA)<br>Advisory Council on Historic Preservation (ACHP) |
| 4. | Environmental Application | "Environmental and Socio-Economic Impact Assessment". | "Environmental Report" (12 Resource Reports). |
| 5. | Filing Format | Hard Copies. | Electronic Media and Hard Copies. |
| 6. | Filing Fee | None. | $19,500.00 |
| 7. | Agency Environmental Impact Statement (EIS) | No. Under *Canadian Environmental Assessment Act*, NEB will prepare a "comprehensive study report" or participate in a "joint review panel report". | Yes for major projects, as required by *National Environmental Policy Act*. |
| 8. | Provincial/State Involvement | Generally informal and limited. Some provinces (e.g. Ontario) take a more active role. | Formal as cooperating agencies in EIS. Specific to each state and project. California tends to receive special status as a co-lead in a joint EIS/EIR. |
| 9. | Request for Further Information | Yes (Information Requests). May be numerous to resolve most issues prior to the Hearing. | Yes (Information Requests). May be numerous requests over several months to feed EIS. |
| 10. | Personal Correspondence with Staff | None once Application filed. | Limited to nil with strict rules against holding *"ex parte"* communication. |
| 11. | Mandatory Public Meetings | Yes. Prior to formal hearing as part of Early Public Notification. Usually held by applicant but CEAA requires NEB involvement. | Yes, at scoping meetings and comment meetings prior to and after issuance of Draft EIS. Meetings run by FERC staff with transcripts taken. |
| 12. | Formal Public Hearing | Yes. (Panel of Board Members.) | Rare occurrence. If it does occur, it takes the form of an Administrative Law Judge recommending to Commission. |
| 13. | Approval Period | 9–15+ months | 19–24+ months |
| 14. | Expropriation / Condemnation Construction Rights | Yes. | Yes. |
| 15. | Federal Precedence over Provincial / State and Local Agencies | Likely but rarely tested in the courts. | Yes. Upheld by U.S. Court of Appeals in the National Fuel Case |

impact, the *Natural Gas Act* does not empower FERC to issue certificates for oil lines or lines carrying other commodities such as carbon dioxide ($CO_2$).

In Canada, the applicant files an Environmental and Socio-Economic Impact Assessment under the Guidelines for Filing Requirements (NEB 1995). In the U.S., the applicant files an Environmental Report (ER) under FERC's regulations which implement the *National Environmental Policy Act of 1969 (NEPA)* (42 U.F.C. 4321 et seq.). The applicant follows *Guidelines for the Preparation of Environmental Reports under the Natural Gas Act* (FERC 1995) as well as an ER checklist updated from time to time and made available from FERC's Office of Pipeline Regulation (OPR). FERC's preferred format for filing Environmental Reports is to have the applicant file a series of Resource Reports covering the traditional gamut of environmental concerns. FERC also requests applicants to comply with FERC's standard Plan and Procedures or describe how their proposals result in superior environmental mitigation (FERC 1994b, 1994c). FERC has conducted numerous well-attended compliance workshops in major U.S. cities to assist pipeline companies in understanding the provisions of FERC's Plan and Procedures, and recently offered separate workshops on Environmental Report Preparation.

There may be extensive formal participation of states in an FERC review process because most agencies see the value in cooperating in a single EIS document. In Canada, the participation of provinces in an NEB Application is generally informal. NEB staff are not permitted to communicate with the applicant's staff once the Application is filed. Communications are routed through the applicant's lawyer. A similar situation has emerged in the U.S. where strict *"ex parte"* rules must be obeyed. Both agencies routinely issue requests for additional information. Unless waived by the NEB, a public hearing is mandatory on pipelines greater than 40 km in length and environmental issues are also examined by the Board's Panel. There is usually no public hearing in the U.S., although an administrative hearing may be ordered if the application is contentious or competitive. The process in Canada may take six months for a straightforward application to more than 12 months for a contentious project. In the U.S., FERC has taken up to 36 months or more to issue a certificate, but there are recent indications that FERC is starting to expedite the process (Tuscarora Gas Transmission Company received a certificate within 19 months of filing its application).

Both the NEB and FERC Certificates clearly grant the power of eminent domain, allowing the applicant to expropriate or condemn land for installation of the pipeline. Less clear is whether the applicant must comply with all provincial/state and local government laws and regulations in the event of a conflict with a Certificate condition or federal law. Legally the federal certificate should take precedence, but some lower-level agencies may not agree. For example, the New York Public Service Commission (PSC) applied its Article VII certification process to the Iroquois pipeline in the late 1980s. The resulting duplicative public hearings and regulatory review were both costly and time consuming for the applicant and confrontational with the PSC. This project is discussed in more detail below. The applicant's only legal recourse in these situations is to sue the lower agency in the courts, an unattractive option, given that the likely outcome is postponement of construction. Accordingly, most applicants on both sides of the border attempt to negotiate a fair resolution of the problem.

A fundamental difference in regulatory approaches of the two countries is the author of the environmental assessment report. In Canada, the NEB makes its decision based on: the applicant's Environmental and Socio-Economic Impact Assessment; applicant responses to information requests; and applicant responses to Board, staff and intervenor questions at a public hearing. In the U.S., however, FERC takes the applicant's Environmental Report (ER) and proceeds to write an Environmental Impact Statement (EIS) based on the ER as well as original research and public input received through a formalized public scoping process. The EIS process is discussed in more detail below.

While *NEPA* in the United States has been in effect for almost 30 years and FERC has developed procedures to implement this legislation in its certification process, Canada is a relative newcomer to formal, legislated environmental assessment. Canada has operated on a discretionary guideline system known as the *Environmental Assessment and Review Process Guidelines Order*, SOR 84-467 (*EARPGO*), since 1974. The NEB implemented *EARPGO* by performing environmental screening of new pipeline projects as part of its normal certification process. The situation changed dramatically on 19 January 1995 with the proclamation of the *Canadian Environmental Assessment Act (CEAA)* (Canada Gazette, Part III, Vol. 128, No. 21, SOR/94-636, SOR/94-637, SOR/94-638 and SOR/94-639). Proclamation of *CEAA* has brought regulatory uncertainty to the pipeline industry as the NEB, Canadian Environmental Assessment Agency (CEA Agency) and applicants struggle with implementation of new environmental requirements overtop a well-understood environmental permitting system. *CEAA* requires major pipeline projects greater than 75 km in length on a new right of way to undergo a "comprehensive study assessment" which is considerably more onerous than a "screening" assessment (Hanebury 1995). For example, cumulative environmental effects, effects of malfunctions and alternative means to the project (not just alternative routes) must be assessed. If the responsible authority concludes that there may be significant environmental effects or there is sufficient public concern, a "review panel assessment" may be triggered.

The Express crude oil pipeline built in 1996 was a test case of the CEAA review process. The project experienced many regulatory problems including: delays in striking a joint review panel with members from the NEB and the CEA Agency chaired by the NEB; lengthy interventions by CEA Agency-funded environmental nongovernment organizations (ENGO's) at a six-week public hearing; a dissenting opinion by one of the four panel members; three appeals (since overturned) to the Federal Court of Appeal in Ottawa by disenchanted ENGOs claiming that the Panel had failed to comply with *CEAA*; an ENGO request to the Supreme Court of Canada to order the Federal Court of Canada to review the environmental approval granted Express by the federal regulators; and a late requirement for a separate NEB Hearing and *CEAA* environmental screening on an accessory 16 km 69 kV powerline feeding a critical pump station. It is evident that both the NEB and CEA Agency are dissatisfied with the way the Express case was handled. A post-mortem report is due to be released in early 1997. In the meantime, Canadian pipeline applicants are proceeding cautiously in the hope that the duplicative requirements will be avoided and that there will not be a requirement for two public hearings, which can happen if a review panel assessment is ordered following the traditional NEB hearing. There are indications that a "Memorandum of Understanding" between the NEB and the CEA Agency may be signed appointing the NEB as a "substitute panel" for a *CEAA* review, although it is also understood that the CEA Agency has identified eight fundamental deficiencies with NEB's process. Alternatively, there are indications that the Minister of Environment overseeing the CEA Agency may not require a "review panel assessment" at all but rather rely on a "comprehensive study report" prepared by the NEB acting as a "responsible authority". This approach implies that the NEB will find that the project is not likely to cause significant environmental effects once mitigation is applied. This also assumes that Section 5 of the *Act* will be amended to correct a legal point of law which permits the Board to be a "Federal Authority" but not a responsible authority.

Whatever the outcome, it is obvious that a solution is required soon or the Canadian pipeline industry may be paralyzed by regulatory uncertainty. The cynic would observe that a political solution may be enforced if the agencies fail to resolve their differences in a timely fashion. For example, the Cabinet of Prime Minister Jean Chretien recently amended regulations under *CEAA* that would exempt the sale of two nuclear reactors to China from full scrutiny (Gregory 1996).

### Provincial/state jurisdiction

For comparative purposes, Table 2 presents a similar outline of the intra-provincial and intra-state pipeline situation using the neighboring jurisdictions of Alberta and Montana as examples. Alberta is in the forefront of developing regulations to mitigate the environmental effects of pipeline construction, as more pipelines are built in Alberta than any other jurisdiction in Canada (more than 240,000 km of pipeline in the ground).

**Table 2. Regulatory comparison of major intraprovincial/intrastate pipeline in Alberta/Montana**

| | Parameter | Province of Alberta | State of Montana |
|---|---|---|---|
| 1. | Legal Authority | Permit to Construct and License to Operate under *The Pipeline Act* | Certificate of Environmental Compatibility and Public Need under the *Major Facility Siting Act*. |
| 2. | Authorizing Agency | Alberta Energy Utilities Board (EUB), Calgary, Alberta | Department of Environmental Quality, Helena, Montana. |
| 3. | Other Provincial/State Agencies | Alberta Environmental Protection, Land and Forest Service<br>Natural Resources Service<br>Agriculture, Food and Rural Development<br>Historical Site Service<br>Fisheries and Oceans | Department of Fish, Wildlife and Parks;<br>Department of Health and Environmental Safety<br>Department of State Lands;<br>State Historic Preservation Office. |
| 4. | Number of Applications/Year | 80–100 | <1. |
| 5. | Environmental Application | Conservation and Reclamation Application for a pipeline with an index number ≥2690 (length in km multiplied by outside pipe diameter in mm) | Environmental Application (for a pipeline >48.3 km in length and 432 mm internal diameter). |
| 6. | Filing Fee | $5,000 (C&R application fee; EUB fee also applies) | Varies based on dollar value of facilities. May reach $200,000+. |
| 7. | Environmental Impact Statement (EIS) | No | Yes (*Montana Environmental Policy Act*). |
| 8. | Mandatory Public Meetings | No, but strongly encouraged. Held prior to filing and run by applicant | Yes, at scoping meetings prior to filing. |
| 9. | Public Hearing | Not usual | Mandatory. Held before a Hearing Examiner. |
| 10. | Approval Period | <2 months on average | 15–36 months depending if pipeline is a utility. |
| 11. | Construction Reclamation Performance Bond | No | Yes. $1,242/km. |

Montana has experienced few recent pipeline projects and is a state lying at some point on a continuum between California or New York which are heavily regulated, and Idaho or Wyoming which are less so.

In 1996, Alberta's Energy Utilities Board (EUB) processed more than 3,000 applications for pipeline permits under *The Pipeline Act*, of which 84 were long enough to have required Conservation and Reclamation (C&R) Approval under regulations of Alberta Environmental Protection (1994). The Montana Certificate of Environmental Compatibility and Public Need incorporates approvals from most state, federal and county agencies whereas the EUB Permit does not. However, the rapid turn-around time for Alberta permits compared to Montana allows the applicant to expeditiously acquire the other permits itself. There is no EIS requirement for pipelines in Alberta, whereas in Montana, an EIS is mandatory under the *Montana Environmental Policy Act (MEPA)*. Regulations under Montana's *Major Facility Siting Act (MFSA)* specify a filing fee calculated as a percentage of the total project cost. The funds would be used to prepare an EIS and to reimburse review agencies for staff time and expenses. The company is also required to post a performance bond. In Alberta, there is a nominal filing fee for the C&R application, regardless of the size of the project and no performance bond. A public hearing is mandatory in Montana. On the Express case, a Hearings Examiner reviewed the case and made recommendations to the Board of Environmental Review, which met in public to formally approve the project (Montana Board of Environmental Review 1996). In Alberta, the EUB expects applicants to resolve environmental and landowner issues through mediation without a formal public hearing. Of the more than 3,000 pipeline applications in 1996, there were only two public hearings held by EUB. The Alberta process can be completed in a fraction of the time required by the Montana process.

There is significant emphasis in Alberta C&R Reports on soil surveys, Environmental Protection Plans (EPPs) and construction alignment sheets. While the C&R does not contain the verbiage characteristic of an EIS document, it contains more specific details on environmental protection measures — stripping topsoil, water crossing methods, timber salvage and so on. The EPP, complete with annotated aerial photomosaic alignment sheets, is designed to be extracted from the regulatory document and incorporated into pipeline construction specifications and contract documents. In this way, the environmental mitigative measures become contractually enforceable and binding on the contractor.

## ENVIRONMENTAL IMPACT STATEMENT

Some major differences between the two countries are evident with respect to the type of EIS document produced at the federal level (Table 3). In Canada, the applicant prepares and pays for its own Environmental and Socio-Economic Impact Assessment. In the U.S., the same is true of the Environmental Report. However, FERC goes one step further in preparing the EIS or hiring a third party contractor if staff are too busy to take on the task. FERC may pay for the EIS out of its budget by assigning its own staff, possibly assisted by FERC's environmental support contractor. However,

**Table 3. Comparison of major gas pipeline. Environmental impact statement parameters in Canada/U.S.[1]**

| | Parameter | Canada | U.S. |
|---|---|---|---|
| 1. | Prepared by | Applicant | FERC (usually by FERC's environmental support contractor or a third party contractor rather than FERC staff). |
| 2. | Paid for by | Applicant | FERC but sometimes by applicant under cost recovery. Indirect control over contractor selection. No direct control over content, cost or timing. |
| 3. | Cost | \$100,000–\$1,000,000+ | \$0–\$1,000,000+ |
| 4. | Preparation Time | 4–12+ months | 13+ months |
| 5. | Draft Circulated to Public | No | Yes |
| 6. | Size of EIS | 300–500 pages | 500–750 pages (DEIS, FEIS) |
| 7. | Environmental Inspection Required | Yes, since 1974 | Yes, since early 1980s. |
| 8. | Post-construction Monitoring Required | As-built, 1 year after and 2 year after reports required to be filed | One and 2 year after reports required to be prepared but not necessarily filed. |

[1] The EIS referred to in Canada is the applicant-prepared Environmental and Socio-Economic Impact Assessment whereas the EIS referred to in the U.S. is the Draft and Final EIS prepared by FERC. The applicant-prepared Environmental Report may cost from \$100,000 to \$800,000 to prepare.

under the principle of cost recovery, the applicant may fund the EIS preparation in the interest of more timely EIS delivery (FERC 1994a). FERC announced its third-party EIS contracting program on 9 February 1994. Tuscarora and Mojave Northward Expansion were the first two projects to take advantage of this option. It appears that the U.S. portion of the Alliance Pipeline Project, from North Dakota to Chicago, will be the third. The dollars can mount up and easily exceed $1 million on a major pipeline. However, the applicant has only indirect control over selection of the third party contractor, and no control over cost, timing or content of the EIS. Some control over these parameters can be exercised by filing a complete and detailed Environmental Report that is directly transferable to the EIS. Environmental data organized by resource reports and milepost tables generated from digital mapping are the most useful to EIS preparers. Following public scoping meetings, field visits and office research, a Draft EIS (DEIS) is written and circulated to a multitude of agencies, citizens and interest groups for comment. The applicant also has an opportunity to comment. The FERC uses public input to revise the DEIS and then issues multiple copies of the Final EIS (FEIS) complete with an Appendix reproducing all the comments received on the DEIS and describing how FERC responded to the comments by modifying the FEIS. Input is also received at public comment meetings where a court reporter records the proceeding verbatim. The DEIS and FEIS specify detailed mitigative measures which the applicant must fulfill before, during and after construction.

In Canada, relevant environmental issues must be described and addressed with appropriate mitigation. The NEB requires identification of a preliminary environmental issues list as a management tool for tracking mitigation and issue resolution. Mitigation details were formerly provided as responses to Information Requests or verbal commitments at the hearing, which were later reinforced as a condition of the Certificate issued by the NEB. However, applicants are now filing detailed EPP's similar to the Alberta model in order to describe specific mitigation measures. The NEB has also issued guidelines for applicants to implement an Early Public Notification Program and has developed a draft framework for intervenor funding. These issues are reinforced by *CEAA* requirements for establishing a public registry and providing intervenor funding.

In the U.S., public information and notification are formally codified under *NEPA*. While some applicants hold their own public meetings prior to FERC scoping meetings, there is a growing cynicism among applicants in the Northeast U.S. that early public involvement merely gives opponents more time to challenge the project, both inside and outside the courtroom. What many observers refer to as "the heart of the EIS" is the analysis of alternatives. This section may include alternative fuel sources (including energy conservation), alternative pipeline systems (whether they are actually proposed as competitive systems or not) as well as alternative routes studied in equivalent level of detail. Also considered in the EIS is the no-action alternative, which examines the consequences of not building the proposed pipeline. Mitigative measures to avoid or minimize environmental effects of the project are provided in the form of conditions concluding the EIS and eventually attached as conditions to any certificate issued. Standard mitigation statements include a requirement that the applicant follow FERC's Plan and Procedures (FERC 1994b,c) or propose equally protective mitigation in advance. FERC conditions its Certificate with a requirement for the applicant to file an Implementation Plan defining how it will meet post-Certificate/preconstruction filing requirements, including how environmental protection measures will be communicated to the contractor (Lake 1993).

Pipeline routing issues are similar on both sides of the border. Both countries require public justification of routing decisions and emphasize the use of corridors (i.e., following existing linear facilities wherever possible). However, the corridor concept is being questioned in some cases. In Alberta for example, the Natural Resources Service discourages wide (>50 m) corridors in some forested areas because the resulting clearing may create a barrier to wildlife movements or increase hunter success to unacceptable levels. In southwestern Ontario, landowners on a recent looping project objected on the basis that the cumulative impact of adding a fourth line crossed a threshold level where the impacts on their tile-drained farming operations were perceived to be excessive and unreasonable. They recommended that the company start a new route anywhere but on their land. There also appears to be a growing awareness that, in some instances, environmental awareness may have been very limited during route selection of older linear developments.

American EIS documents are written to withstand legal challenge. From time to time, FERC has had its certification decisions challenged without success in the courts by competing pipeline companies, state agencies like California Public Utilities Commission or environmental interest groups. Until recently, NEB certificates were rarely challenged on legal grounds. Introduction of *CEAA*, however, has provided considerable opportunity for legal challenge. The process withstood several appeals in the Express case. More legal challenges can be expected as ENGOs take advantage of the intervenor funding provisions of *CEAA* and those proposed by the NEB as well as the regulatory uncertainties in implementation of *CEAA* on NEB projects. Canada appears to be following the litigious lead of the United States where teams of solicitors are in place early on to advise the applicant how to avoid a wide array of legal minefields or to advise opponents on legal plays that may cause the project to be delayed or cancelled.

ENGOs have become more involved in large pipeline applications in Canada then in the past and which may, in part, be the result of provisions for intervenor funding under *CEAA*. In the event that the framework for intervenor funding is adopted by the NEB, then increased participation by ENGOs can be anticipated. The scrutiny recent projects have received by ENGOs has resulted in increasingly intensive preconstruction surveys and more detailed mitigation. The effect of this increased scrutiny is that each new major project tends to "raise the bar" or quality of the application several notches.

## RECENT TRENDS IN MITIGATION PLANNING AND CONSTRUCTION PRACTICES

### Threatened and endangered species

If requested by the appropriate agency, applicants in the U.S. are required to search for special status species on portions of their pipeline rights-of-way to meet the *Endangered Species Act (ESA)* and any similar state legislation. Large teams of fish and wildlife biologists and botanists are assembled to survey for special status species during critical periods of their life cycles. Voluminous reports are filed with FERC. Section 7 of the *ESA* may require FERC to prepare a Biological Assessment (BA) documenting possible impacts on habitat or populations of federally listed or proposed threatened and endangered species and to submit the BA to the U.S. Fish and Wildlife Service (FWS). In the BA, FERC will propose mitigation and identify whether there is or is not an effect on the species in question. In the event of an "effect", FERC and the FWS must enter into "formal consultation". The FWS will, in turn, prepare a Biological Opinion (BO) using a worst-case construction scenario documenting any potential impacts and prescribing mitigation and compensation which must be followed to minimize impacts if a reroute cannot be made to avoid the habitat or population. The sole concern of the FWS is the protection of the species in question. The FWS is not bound by project economics or practicality when it proposes mitigation or compensation for loss of habitat. This fact has forced some applicants into: rerouting; hiring scores of biologists as construction monitors; rescheduling construction activities in sensitive areas; or purchasing large tracts of land to compensate for loss of habitat at a 3:1 or 5:1 ratio.

Threatened and endangered species in Canada receive considerably less protection than in the U.S. and only on an *ad hoc* basis. The Committee on the Status of Endangered Wildlife in Canada (1996) publishes an annual list of species determined to be threatened, endangered or extirpated. The list currently carries no official protection, although this would change for at-risk-species on federal lands if a recently tabled bill (Bill C-65) is passed (Steinhart 1996). Applicants to the NEB routinely conduct rare vascular plant and wildlife surveys along segments of the route that traverse native vegetation. While many of these surveys are completed after receipt of a Certificate, contingency measures (including rerouting) are included within the application in the event that rare and endangered vascular plants or wildlife are discovered during the surveys.

### Cultural resources

As part of its EIS document, FERC must address impacts on cultural resources (archaeological and historic sites and features) and paleontological resources. Applicants are required by Section 106 of the *National Historic Preservation Act* to survey the route as recommended by the State Historic Preservation Office, BLM or USFS, and mitigate potential impacts. Large teams of archaeologists are assembled to walk the "Area of Potential Effect" (or APE) along either side of centerline. Where properties are found that are listed or eligible for listing on the National Register of Historic Places, the applicant must either avoid the site by rerouting (the preferred practice) or conduct mitigation in the form of scientific excavation of the site. Mitigation must be complete before construction can begin on the entire pipeline segment where the property was found. Scientific excavation of sites can be painfully slow and expensive.

Considerable confusion exists on the cultural resource regulatory process in the U.S. due largely to the myriad of agencies involved. Unlike Canada where cultural resources are generally a provincial responsibility handled efficiently and expeditiously, FERC must deal with several organizations in the U.S. including federal land managing agencies such as the BLM and FS, SHPOs, and the Advisory Council on Historic Preservation. Each agency jealously guards its own turf and insists that its procedures are superior to its counterparts. Given that pipelines often cut across several jurisdictional boundaries, there is a great potential for regulatory gridlock. Commencing in late 1990, FERC reluctantly began signing individual project Programmatic Agreements (PAs) with the various agencies to demonstrate its compliance with Section 106. The PA establishes a formal procedure for evaluating cultural resources data supplied by the applicant and making recommendations for mitigation. In the early 1990s, FERC and the Advisory Council attempted to negotiate a Nationwide Programmatic Agreement to make project-specific PAs obsolete but appears that these efforts have now been abandoned. While these developments are evolving, U.S. pipeline applicants are under considerable uncertainty about lead times and responsibilities for cultural resource approval. The best advice is to begin cultural resource inventories as early in the project as feasible, since these approvals tend to be on the critical path.

The Canadian situation is more straightforward. From a resource protection perspective (as opposed to a regulatory process perspective), cultural resources in

Canada are given roughly the same level of protection as in the U.S. The major difference is that protection is achieved more quickly and with less confusion and agency posturing. Avoidance of significant sites is the preferred practice in both countries.

Accommodation of the concerns of First Nations in Canada and Native Americans in the U.S. continues to be requisite components of pipeline applications on both sides of the border. This is particularly applicable in British Columbia where few treaties were signed and aboriginal land claims cover more than 100% of the province's land base (i.e., there are overlapping claims by different groups). There is increasing pressure on both sides of the border to deal in good faith with aboriginal groups and to hire native workers as much as possible (see Mohun and Halverson 1993).

### Wetlands

U.S. policy is that there shall be "no net loss of wetlands". Pipeline companies argue with varying degrees of success that construction is only a temporary impact and does not represent a net permanent loss of wetlands if existing contours and drainage patterns are replaced. Nevertheless, large teams of wetland scientists are assembled to delineate wetlands along centerline using federal agency manuals as a guide. FERC considers wetland impacts in its decision-making and conditions certificates with a directive to follow its Procedures (FERC 1994c). FERC's philosophy seems to be that compliance with the Procedures will categorically result in no net loss of wetlands. One company in northern California protected more than 300 wetlands of 13 different types using 10 different construction procedures on a recent 370 km pipeline. Many of these were in fact "dry" wetlands. Mitigation measures included narrowing the construction right of way width, salvaging topsoil over the trench, replacing a hydrologic seal with bentonite, and replanting with native wetland vegetation (FERC and CSLC 1995). The same company faced requirements for off-site compensation (i.e., acquisition of similar wetlands away from the right of way) which were equally as onerous as the mitigation requirements.

What may be a "vernal pool" in California is a "slough" in Saskatchewan. Although wetlands have traditionally received little protection in Canada, there is increasing awareness of the need. For example, Ducks Unlimited and the North American Waterfowl Management Plan have made considerable strides in preserving and creating wetlands, especially in the prairie provinces which are generally regarded as the "North American duck factory". Pipeline companies are coming under pressure to preserve wetlands in regions with high waterfowl production. Protection primarily equates to avoidance with minor reroutes, crossing during a time of year when birds are not nesting and reestablishment of the wetland contour. Pipelines in wetland areas with little waterfowl production are subject to limited or no requirements. Many Canadian pipeline companies unknowingly practice wetland preservation every time they opt for winter construction in northern muskeg areas.

### Water crossings

Most water crossings in both countries are still installed using the open cut crossing technique, although British Columbia (B.C.) is typical of some jurisdictions which require the applicant to study the feasibility of horizontal directional drilling (HDD), boring or isolated ("dry") crossing methods (such as flume, dam-and-pump, diversion) before an open cut crossing method will even be considered on most moderate sized, fish bearing watercourses (B.C. Pipelines Watercourse Crossing Guidelines Committee 1996). Open cut crossings will become increasingly less common in both countries, even though most practitioners recognize that a practical and effective solution is to cross streams quickly during low water and when fish are less sensitive to disturbance (i.e., in the appropriate timing "window"). FERC's current Procedures (FERC 1994c) include a requirement for fluming and a number of other detailed precautions at minor streams (<3.1 m wide) that contain sensitive fisheries. The federal *Fisheries Act* is the legislation in Canada used to limit or prevent the release of deleterious material into fish-bearing watercourses and ensure no net loss of fisheries habitat. Nevertheless, each region appears to interpret the *Fisheries Act* and what constitutes "deleterious material" in a different manner. Ontario and British Columbia are increasingly applying more onerous mitigation and compensation measures and penalties on non-compliance for discharge of sediment into fish-bearing watercourses under the auspices of the federal *Fisheries Act*. Ontario, for example, is requiring applicants to prepare erosion and sediment control plans. Proposed changes to this *Act* would transfer additional administration of the *Act* to each province. While this could allow consistent policy to be administered throughout a province, some ENGOs strongly reject the proposal since it would weaken the federal governments role in onshore fisheries concerns (Scott 1996).

Canada is catching up to the U.S. in application of HDD as the 'best management practice' crossing method. Now that the technology is readily available in Canada and numerous crossings have been successfully completed, directional drilling will continue to be more widespread, where feasible, as companies gain experience with the technique and costs start to come down. The environmental advantages are obvious since it is often possible to drill under both the river bed and steep approach slopes from one drilling location. However, a B.C. pipeline company was recently charged under *The Fisheries Act* for releasing drilling mud into a watercourse during an HDD frac-out. Boring of small to moderate size watercourses in a manner similar to irrigation canals is also becoming more common if substrate and groundwater conditions permit. A uniquely Canadian application of the boring method on muskeg streams is to excavate a bellhole and pump it dry overnight in order to freeze the trench walls sufficiently to allow a boring machine safe access to the bore pit (Houser and Eccles 1993). As a result of increasing pressure for negligible impact during water crossing construction and the relatively high cost of drilling, there appears to be renewed interest in installing aerial crossings.

### Topsoil conservation

In Canada, there is more emphasis on topsoil conservation on both agricultural and non-agricultural lands than in the U.S., although the Americans have recently made major improvements. The norm in Canada is to strip over the trench and under the spoil pile on cultivated lands (Mutrie and Wishart 1987). In some situations, companies strip the entire right of way and follow-up with deep ripping to relieve compaction prior to topsoil replacement. The protection of native prairie in southern Alberta and Saskatchewan has emerged as a major environmental issue on recent projects. Several companies have developed innovative procedures to protect the sod layer by narrowing the right of way, instituting strict traffic controls, severely restricting grading and using specially designed equipment such as the "Prairie Protector", modified rangeland sweeper and hydraulic step blade (Blair and Houser 1992). In the U.S., trench line stripping (double ditching) used to be the norm although FERC's Plan (FERC 1994b) now requires either "trench plus spoil" or "full right of way" stripping on agricultural lands. On agricultural lands in Canada, experienced soil surveyors map topsoil depth and problem soils to trench depth on center-line at a scale of 1:15,000 or less. The soils report is incorporated into the EPP which includes several combinations of stripping widths and depths, including three-lift soils handling or overstripping in problem soils and special machinery for special situations (e.g., frozen topsoil). FERC, however, does not require on-the-ground soil surveys but allows applicants to rely on existing mapping by the Soil Conservation Service. Pipeline reclamation in both countries is becoming more sophisticated with increasing reliance on erosion control products and procedures (silt fences, tackifiers, straw crimping, waterbars, subdrains, bioengineering) and use of native seed.

### Environmental inspection and training

In Canada, there is less emphasis on monitoring and more on environmental inspection, which is defined as the assignment of one or more environmental specialist(s) as part of the owner company's inspection team to enforce the environmental specifications in the contract documents (Mutrie 1979). Environmental inspectors have been used during construction of major NEB pipelines since 1974 and have also been employed on U.S. projects since the early 1980s. The annual training course on Pipeline Environmental Inspection offered by the Petroleum Industry Training Service (PITS) in Calgary was the first of its kind in North America and has attracted representatives from FERC staff and U.S. pipeline companies. FERC's Plan (FERC 1994b) requires the use of environmental inspectors during construction. The norm used to be to assign one environmental inspector per pipeline spread but recent projects on both sides of the border have had up to four full-time inspectors per spread in addition to environmental monitors advising on specific resources such as wildlife, rare plants and archaeology. Part of the environmental inspector's job is to conduct environmental training of all personnel to alert them to specific environmental concerns on each particular project.

### Compliance enforcement

Perhaps the biggest difference between Canada and the U.S. is in the area of legal enforcement. It has been Canadian practice to pass tough environmental legislation and regulations, but not to strongly enforce them. Regulatory agencies tend to be timid and give industry multiple warnings and notices rather than non-compliance orders, fines or arrest warrants. American environmental laws are enforced more rigorously as evidenced by the Iroquois pipeline case.

Iroquois is a 600 km natural gas pipeline built in 1991 from Iroquois, Ontario to New York City. Following a four-year criminal investigation by the U.S. Attorney's Office, the company pleaded guilty to four felony violations of the *Clean Water Act* and will pay $18 million in fines (Waldie 1996). Iroquois must also clean up 30 wetlands not fully restored after construction and monitor the pipeline for 10 years to ensure there are no safety problems. The company also admitted it failed to install numerous trench breakers and backfilled the trench with rocks greater than 46 cm in diameter. Iroquois also agreed to pay $4 million to settle allegations that the company broke New York State environmental and safety regulations. Two company officials also pleaded guilty to three felony violations and faced a maximum penalty of a year in jail and up to $100,000 in fines. However, both will receive six months of home confinement and help U.S. prosecutors convict other violators. Other notable American cases include the $1 billion settlement for the Exxon Valdez oil spill, and a $36 million settlement in fines and damages agreed to by a pipeline company resulting from destruction of numerous archaeological sites in Alabama. Such fines are unheard of in Canada, but may start to show up if ENGO's continue to pursue weaknesses in Canadian regulatory enforcement.

### Agency reimbursement

Cost recovery is an accepted form of agency reimbursement for handling pipeline applications in the U.S. and is being considered by the Canadian Environmental

Assessment Agency as well. FERC's Third Party EIS procedures are a good example (FERC 1994a). However, regulatory agencies in California and other states increasingly understand that pipeline companies require fast-track approvals to compete in the economic marketplace. The agencies also understand that companies are anxious to avoid prosecutions and fines as described in the previous section. Using whatever permit, approval or referral legally available, there is a growing trend for some agencies to actively solicit and accept money and/or equipment from applicants in exchange for expediting the approval process. For example, Express Pipeline Inc. agreed to pay the State of Wyoming up to $20 million for 16 km (10 miles) of right of way across state lands provided the pipeline could still be built in 1996. The applicant stated that this payment was in no way an admission that the Express Pipeline would cause an adverse economic impact on the state, but that it was "in recognition of the economic impact to Express if the project is delayed" (Barron 1996).

Many state agencies have had their budgets slashed dramatically and are scrambling to keep their key staff and programs in place. On a recent California pipeline, the pipeline company funded agency staff positions, vehicles, computers and other necessities totaling more than $200,000 in exchange for the agency's cooperation in meeting the applicant's tight permitting schedule. The same agency also required the applicant to spend hundreds of thousands of dollars on off-site land purchases as compensation for loss of habitat on the right of way. The cynic would observe that this practice goes beyond the principle of cost recovery, and that a sophisticated form of graft or extortion has evolved reminiscent of business dealings in some third world countries. This practice is much less prevalent in Canada, even though most provincial and federal agencies in Canada have also suffered extensive budgetary cutbacks. Companies and agencies would be well advised to avoid this practice because it creates an awkward situation and could lead to poor management decisions.

## CONCLUSIONS

There is a high degree of environmental protection achieved on pipeline projects in both Canada and the U.S. The U.S. regulatory process is longer and more expensive than Canada's, although this gap is closing quickly since some confusion and uncertainty remains following the recently passed *Canadian Environmental Assessment Act*. Environmental permitting in both countries is the critical time element for project management. Many mitigation measures in the U.S., and increasingly in Canada, represent a situation of diminishing returns; i.e., the limit of real environmental protection has already been reached and any more expenditure of effort and money realizes no net environmental gain. Nevertheless, the expectation of some agencies and ENGOs is for ever-increasing study and mitigation for each application.

Pipeline practitioners from each country can learn valuable lessons from each other. Canadians can improve in the areas of: institutionally integrating the principle of environmental impact assessment in pipeline permitting; endangered species protection; better wetland protection; and compliance enforcement. Laws and regulations which governments do not intend to enforce should be removed. Americans can improve in the areas of: topsoil conservation; pragmatic approaches to effecting real (as opposed to perceived) environmental mitigation during construction; and following Canada's lead of hiring more Environmental Inspectors than environmental lawyers.

## ACKNOWLEDGEMENTS

The authors wish to express their thanks to the following people for their comments on this paper: Ian Scott of the Canadian Association of Petroleum Producers, Calgary, AB; Dr. Richard Skarie of Natural Resource Group Inc., Minneapolis, MN, Larry Sauter of the Federal Energy Regulatory Commission, Washington, DC; and Pat Farmer, Western Technology and Engineering Inc., Helena, MT.

## REFERENCES

Alberta Environmental Protection. 1994. Guide for pipelines pursuant to the Environmental Protection and Enhancement Act and regulations. Edmonton, Alberta, March.

B.C. Pipeline Watercourse Crossing Guidelines Committee. 1996. A decision framework for pipeline watercourse crossings: Interim working report. Vancouver, British Columbia, July.

Barron, J. 1996. Land Board calls for more study. Casper Star Tribune. Casper, Wyoming, 13 June.

Blair, G.R. and M. Houser. 1992. Soil conservation innovations: construction equipment modifications to satisfy environmental concerns. In: Proceedings of the 11th International Conference on Offshore Mechanics and Arctic Engineering. Calgary, Alberta, June.

Committee on the Status of Endangered Wildlife in Canada. 1996. Canadian Species at Risk. Ottawa, Ontario, 17 September.

Federal Energy Regulatory Commission. 1994a. Handbook for using third-party contractors to prepare environmental assessments and environmental impact statements. Washington, D.C., October.

Federal Energy Regulatory Commission. 1994b. Upland erosion control, revegetation and maintenance plan. Washington, D.C., December.

Federal Energy Regulatory Commission. 1994c. Wetland and Waterbody Construction and Mitigation Procedures. Washington, D.C., December.

Federal Energy Regulatory Commission. 1995. Guidance manual for environmental report preparation. Washington, D.C., August.

Federal Energy Regulatory Commission and California State Lands Commission. 1995. Tuscarora natural gas pipeline project — final environmental impact report/environmental impact statement. Washington, D.C. and Sacramento, California, April.

Gregory, R. 1996. Ottawa changes rules to sell Candus. The Globe and Mail. Toronto, Ontario, 8 November.

Hanebury, J.B. 1995. Canadian Environmental Assessment Act: A primer. National Energy Board. Calgary, Alberta, 4 April.

Houser, M. and R. Eccles. 1993. Effectiveness of horizontal boring operations for stream crossings in west central Alberta. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec, 19–22 September.

Lake, D.J. 1993. Preconstruction planning for environmental compliance of natural gas pipeline projects. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec, 19–22 September.

Mohun, E. and D. Halverson. 1993. Reconciling aboriginal and industrial interests in right-of-way management. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec, 19–22 September.

Montana Board of Environmental Review. 1996. Findings of fact, conclusions of law, certificate of environmental compatibility and public need and final order. Helena, Montana, June.

Mutrie, D.F. 1979. Environmental supervision of construction. MA Thesis. University of Waterloo, Ontario.

Mutrie, D.F. and D.M. Wishart. 1987. Evaluation of alternative techniques and equipment for conserving topsoil during pipeline construction in Canada. In: Proceedings of the Fourth Symposium on Environmental Concerns in Rights-of-Way Management. Indianapolis, Indiana, 25–28 October.

National Energy Board. 1995. Guidelines for filing requirements. Calgary, Alberta, 22 February.

Scott, I.F.H. 1996. Proposed changes to Federal Fisheries Act. In Re CAPP, newsletter of the Canadian Association of Petroleum Producers. Calgary, Alberta, July.

Steinhart, D. 1996. Endangered species bill gets lukewarm reception. Calgary Herald, 1 November.

Waldie, P. 1996. Two TransCanada executives plead guilty in U.S. The Globe and Mail. Toronto, Ontario, 24 May.

---

## *BIOGRAPHICAL SKETCHES*

***Dean F. Mutrie***

*President, TERA Environmental Consultants (Alta.) Ltd., 205, 925 - 7th Avenue S.W., Calgary, Alberta, Canada T2P 1A5*

Dean Mutrie holds degrees in Environmental Studies from the University of Waterloo and has focused exclusively on the pipeline field since 1975. He co-founded the annual Pipeline Environmental Inspection course offered by the Petroleum Industry Training Service and has instructed numerous environmental compliance courses offered by FERC, BLM and U.S. pipeline companies.

***Karl B. Gilmore***

*Senior Environmental Planner, TERA Environmental Consultants (Alta.) Ltd., 205, 925 - 7th Avenue S.W., Calgary, Alberta, Canada T2P 1A5*

Karl Gilmore holds a B.Sc in Wildlife Biology from Washington State University. He has worked on pipeline applications and pipeline related studies since 1978. Mr. Gilmore has prepared and directed numerous environmental applications for both interprovincial and provincial pipeline projects.

# Address Environmental Concerns with Real Data

**Logan A. Norris**

Many environmental concerns about rights-of-way (ROW) siting, construction and management can be addressed most effectively with scientific data from field- and laboratory-based research and monitoring programs. The most useful data will come from efforts developed by well qualified individuals using a detailed plan of work, including careful documentation, and that includes critical peer review of the results. The interests of the public and of the entities managing ROW will be served best by an increase in organized research and monitoring efforts. The basic tenet of this paper is that having sound technical knowledge (including data) about ROW programs will help you address the environmental issues and concerns that involve ROW siting, construction and management. Examples from research and from the practice of rights-of-way management are used to illustrate this point.

*Keywords*: Rights-of-way, monitoring, water quality, buffer strips

## INTRODUCTION

Well designed and carefully managed rights-of-way (ROW) are essential in providing safe and reliable service to customers. There are, however, many concerns about ROW siting, construction and maintenance; some examples include aesthetics, effects on soil, water and wildlife habitat, effects from the use of herbicides, and the effect of electrical and magnetic fields (EMF) on human health. The reasons these are of concern range from a lack of agreement in society about basic values to misinformation and fear of the unknown.

Sound decision making for purposes of policy, regulation, management, and even public education requires knowledge about these kinds of issues. Some of these concerns are able to be better addressed with data than others. While data may not help in discussions about values, data are very relevant in helping address technical issues. Even a concern about aesthetics can be evaluated with quantitative techniques, especially when dealing with human preferences. Some quite innovative image capture technology for visually displaying alternatives is available today, and it can be used for evaluating (and explaining) ROW development and management alternatives (Sheppard 1989; Johnson, Brunson, and Kimura 1994).

Failure to adequately address technical issues with real-world data has significant consequences, including the following:

- increased difficulty in reaching agreements, either those that are voluntary and lead to helpful collaborative arrangements, or those mandated for regulatory purposes;
- more frequent legal actions that stop or slow the process, resulting in increased costs, lost productivity and often no net-gain in benefit to anyone;
- increased difficulty in general public relations, sometimes manifested in unnecessarily contentious hearings on setting service rate schedules;
- increased regulatory control, with its attendant increased operational costs, lack of flexibility and often poor level of cost/benefit; and
- more suits for damages, a lack of data can seriously impair the ability to respond to allegations of damage. Hard data can be useful in verifying what was done, and they can show the responsible nature of the enterprise. In many instances, hard data can directly address the charges.

The basic tenet of this paper is that having sound technical knowledge (including data) about ROW programs will help address the environmental issues and concerns that involve ROW siting, construction, and management. Knowledge is more than just data, but data play a crucial role. Having knowledge means not assuming or guessing; you can know. The strength and extent of the data increases the certainty with which you know.

- Without data, you can only think something is so.
- With data, you can test it, determine whether it is or is not, and then show others.

The author's basic argument is illustrated by the Greenlane Project installed by Bill Bramble and Dick Burns nearly 45 years ago on an electric utility ROW in Pennsylvania (Bramble and Burns 1983). In this simple experiment they installed large plots where different applications of chemical and non-chemical methods of controlling the tall-growing vegetation were applied over time. The responses of the vegetation and of the wildlife have been followed nearly continuously, since the mid 1950s. The results provide real-world data of the positive effects on wildlife habitat on a ROW from vegetation management strategies that include herbicides. It is perhaps the most widely cited study of its type in this industry, and it has provided invaluable data to help deal with regulatory, policy, and management questions, as well as the concerns of the public. An organized research plan and a carefully conducted data collection strategy were essential to the success of this effort.

In this paper, the importance of organized data collection as part of the effort to improve decision making is emphasized. An example from research and an example from management or practice illustrate key concepts.

## DATA COLLECTION IN THE MANAGEMENT OF ROW

Date collection is not foreign to ROW managers. Data frequently are collected on such matters as accident rates, return frequency for tree-trimming, stem density and height of vegetation on ROW, and maintenance cost per ROW-mile. These data, however, are primarily for management from a business standpoint. They do not relate particularly to environmental concerns. Data also can help address environmental concerns, but only if it is collected in an organized, technically sound and credible way. Research and monitoring are the two areas in which organized data collection can be helpful in meeting the needs of the ROW industry.

### Research

Research is one of the processes where new knowledge is generated. It is the scientific process by which hypotheses are tested or specific information needed to solve a problem is generated. It is where we learn something new! Research is most often done by research or specialty organizations, using technical specialists in the discipline for design and conduct of the work.

### Monitoring

Monitoring verifies or tests outcomes. Monitoring is of three types: compliance, effectiveness, and impact.

Compliance monitoring is used to verify that, or how, something was done. It is the vehicle by which we check to be sure something was done the way it was intended to be done.

Effectiveness monitoring focuses on the effectiveness of a treatment or strategy, verifying the efficacy and efficiency with which a management goal is attained. Compliance and effects monitoring are often designed by ROW managers and staff and are carried out by the operational branch of the organization managing the ROW.

Impact monitoring focuses on the effects of management actions on associated values, which are often environmental in nature, such as measuring the effects of a practice on water quality or wildlife abundance. Impact monitoring often is designed and carried out by discipline specialists who may be in or external to the management organization.

Most of the monitoring done in ROW management is for purposes of compliance or effectiveness. Much less focus is on measuring impacts, and this is the area in which ROW managers can make the greatest gains in their level of knowledge relevant to environmental concerns about ROW siting, construction, and management.

An example from research and an example from the practice of ROW management will illustrate these ideas.

## AN EXAMPLE FROM RESEARCH

Environmental Consultants, Inc. (ECI) carried out a research project to determine the effectiveness of buffer zones in protecting water quality in connection with the use of herbicides. This project was motivated by the ROW managers' need to know how to effectively design buffers strips that allowed greatest operational flexibility, but which still ensured protection of water quality. The public wanted to know if the buffers being used were working, and the New York Public Service Commission agency required the industry to verify (by monitoring) that the buffers were achieving protection of water quality goals. This project was funded by the Empire State Electric Energy Research Corp. and was conducted in cooperation with New York State Electric and Gas Corp. and Niagara Mohawk Corp. This effort is reported in more detail by Norris and Charlton (1995).

While the effort had several parts, the key research component concerned determining the effects of buffer strips of varying width and vegetation density on spray deposition in the buffer zone. The goal was to answer the question, how wide must a buffer be to protect water quality? Regulators wanted to be sure

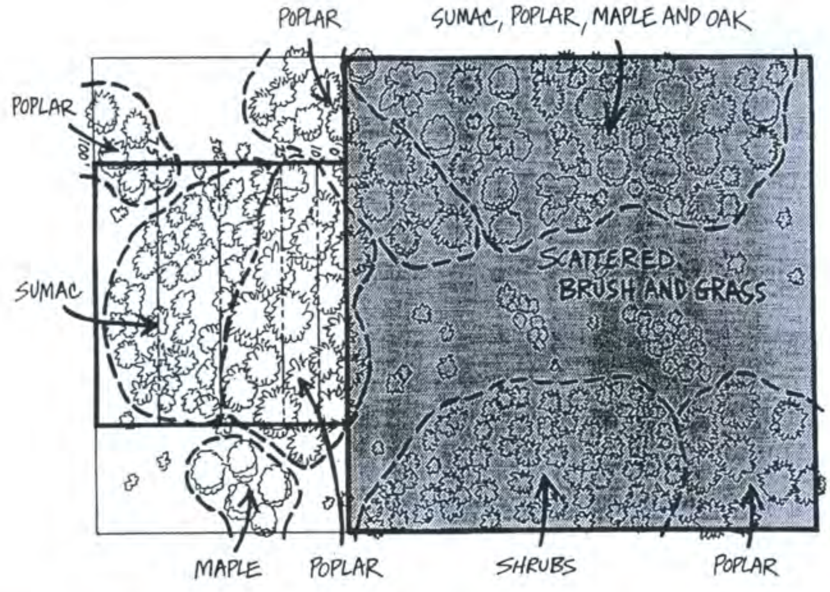



Fig. 1. Schematic of a treatment area on a right-of-way, with a buffer zone and string arrays downwind and perpendicular to the edge of the treatment area. There was a single string array of approximately 185 m in length at 0, 3, 7.6, 15.25, 22.9 and 30 m from the edge of the treatment area into the buffer zone (Norris and Charlton 1995).

water quality was being protected, as did ROW managers, but managers also wanted to know if buffers could be narrower, and therefore less restrictive on operations while still achieving the fundamental goal of protecting water quality.

In this study, string was used to collect spray drift and deposition. Figure 1 shows one installation, where 185 m of string were arrayed (downwind) at six distances from the edge of the treated area location. The 185 meters of string provided a one-sided longitudinal surface area of about 1628 $cm^2$, or the same surface area represented by seven $15.25 \times 15.25$ cm spray cards.

Vegetation density at test sites and their adjacent buffer area were placed in categories of light (< 1,500 stems per acre), medium (1,500–3,000 stems per acre) and heavy (> 3,000 stems per acre). Each site was treated three times by a high volume foliar method, and then three more times by a low volume basal method. In each case, the spray mix was the same as is normally used, except it contained a dye rather than an active herbicide ingredient. Application was made by an experienced contractor spray crew using their normal procedure. The string was collected for analysis of the spray deposit after each application.

An example of the data from this study is shown in Fig. 2. The results are expressed as micrograms of herbicide deposited per square foot at each distance from the edge of the treatment area into the buffer zone. This diagram shows a marked decrease in deposition with distance from the edge of the treatment zone. By knowing the deposition on a surface area basis, it is possible to calculate the equivalent concentration in water, if there had been a water body at that location. Figure 2 has three horizontal lines in the body of the diagram that show the concentration of herbicide that would

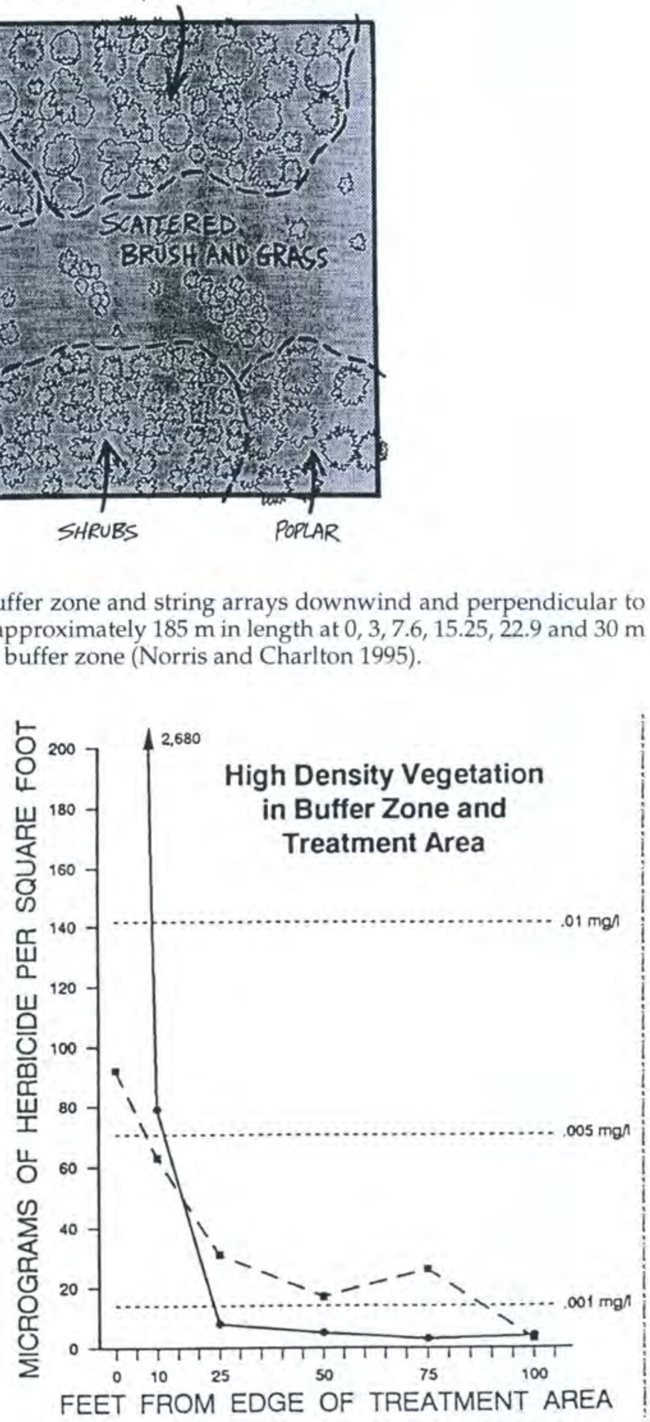



Fig. 2. Calculated deposition of herbicide in the buffer zone following two methods of herbicide application (Norris and Charlton 1995). The concentrations of herbicide (mg $l^{-1}$) in water 0.15 m deep resulting from specific levels of deposition are shown by the horizontal dashed lines. Note: The 0.03 mg $l^{-1}$ concentration is the lowest concentration criterion in Table 1 for the protection of human health and populations of commonly abundant aquatic organisms.

occur in water 0.15 m deep, if deposition occurred at the level shown on the vertical axis.

From these data, and knowing the water quality criterion to be met, it is possible to establish the width of the buffer needed to achieve a specific water quality goal. For instance using the data in Fig. 2, if the water quality goal was not to exceed a maximum of 0.005 milligram of herbicide per liter (ppm) of water, a buffer strip of 3.67 m (12 feet) would meet the goal. To allow for uncertainty, a buffer of 7.6 m (25 ft) would provide a significant margin of safety in meeting this water quality criterion.

The results of this test, conducted under operational conditions on an electric utility ROW have provided a quantitative basis for selecting operational buffer widths in other areas. For instance, the results from this study are the basis on which the buffer width strategy has been established for an Environmental Impact Statement (EIS) for vegetation management on electric utility ROW on the Allegheny National Forest (USDA Forest Service 1997). When combined with an operational monitoring program to verify the adequacy of these buffer widths, managers, the regulatory authority, and the public will develop a high degree of confidence that water quality goals are being met.

**Table 1. Water Quality Criteria[1]**

| Herbicide and commercial product | Water quality criterion[2] (mg $l^{-1}$) |
|---|---|
| Picloram (as Tordon® K) | 0.07 |
| Fosamine ammonium (as Krenite®) | 1.0 |
| Glyphosate (as Accord®) | 0.7 |
| Triclopyr (as Garlon® 3A) | 0.5 |
| Triclopyr (as Garlon® 4) | 0.03 |
| Imazapyr (as Arsenal®) | 5.0 |
| Metsulfuron methyl (as Escort®) | 6.9[3] |

[1] from Norris and Charlton 1995, USDA Forest Service 1997.
[2] 1 mg $l^{-1}$ is 1 part per million. These criterion will provide protection of human health and populations of commonly abundant aquatic organisms.
[3] A water quality criterion for metsulfuron methyl was not included in Norris and Charlton (1995), but the same procedure was used to calculate the water quality criterion for metsulfuron methyl here. In this case, it is based on 0.01 × lowest reported NOEL, a 55 kg body weight, and 2 liter per day water consumption by a human (USDA Forest Service 1997).

## AN EXAMPLE FROM PRACTICE

The water quality monitoring plan developed by ECI for the Allegheny National Forest EIS is an example from practice. It provides a strategy by which Allegheny Power Co. and GPU Energy, cooperatively with the Allegheny National Forest, will verify that the buffer strategies are protecting water quality on the Allegheny National Forest. The monitoring plan has three components.

### Component 1. Water quality criteria

A monitoring program to verify protection of water quality requires criteria against which the program can be judged. Protecting water quality in this case means not introducing herbicides into water at levels that are harmful to the health of humans and other mammals that use the water, or to aquatic species.

It would be most helpful if there were established regulatory water quality standards, but these exist for few herbicides. The risk assessment strategy, however, by which such standards are set is well founded in science, relying on the established base of toxicological information for the chemical and exposure scenarios appropriate to the situation. For this program, we have used the term water quality criteria, rather than water quality standard, since the latter term has a regulatory connotation that does not exist in this case.

Based on the data displayed in the EIS (USDA Forest Service 1997) and the water quality criteria in Norris and Charlton (1995), water quality criteria were identified that will protect human health and populations of common aquatic species (Table 1). Each chemical has its own specific criterion, reflecting the differences in their inherent toxicity. In some cases the criterion is based on the response of aquatic species because these are the most sensitive; but in others, the criterion is based on the sensitivity of mammalian species. The criterion for each chemical is determined by the response of the most sensitive type of organism. The values in Table 1 provide a margin of safety of at least 100 for mammals (including humans) and does not exceed 0.1 times the lowest reported median tolerance limit for aquatic species. It is the lowest of these two values that are used in Table 1.

### Component 2. Monitoring for herbicides in water

This portion of the plan describes the process by which a direct measure of water quality is obtained. It relies on collection of water samples by automatic sampling equipment and the chemical analysis of a sub-set of the samples or their composites collected in this manner.

The key components of this portion of the plan include the following:

- identification of laboratories capable of the specific analyses and coordination with them concerning sample size, containers for the samples, and their storage and handling to ensure reliable results;
- the basis for specific site selection, including the location of samplers;
- sampling schedule, including pre- and post-treatment samples, and samples collected in connection with the first rainstorms after herbicide application;
- precautions to prevent sample contamination which would result in inaccurate estimates of water contamination; and
- methodology for data analysis and reporting.

This segment of the plan provides managers with specific quantitative data on the level of herbicides in water at several locations. The monitoring effort is focused on the period shortly after application and after the first rainstorm when experience at other locations has indicated herbicides are most likely to occur in the water. Further, through a system of sample compositing, the cost of chemical analyses is greatly reduced, but the flexibility for more detailed analysis is retained.

The results from this effort will provide managers with quantitative data with which they can determine if the buffer strip strategy is achieving the water quality protection goal. If it is, they can proceed with confidence, and those interested in (or critical of) their programs will become more confident of their ability to manage rights-of-way without adverse environmental impact. If the monitoring shows the strategy to be inadequate, managers have a basis for adjustment and a baseline against which they can measure progress towards the goal.

### Component 3. Detecting herbicides in the buffer zone

This is an indirect measure of the effectiveness of buffer strips in protecting water quality. It rests on two assumptions as follows:

- the presence of herbicides in the buffer zone will be evident from herbicide damage to vegetation in the zone; and
- a lack of evidence of herbicide damage to vegetation close to the body of water is evidence that the buffer zone was successful in preventing entry to the water.

This indirect measure was developed by Rufin Van-Bossuyt, Jr. (Board of Governors, Environmental Consultants, Inc., Southampton, PA) to complement, not replace, the direct measurement of herbicide residues in the water. Water quality monitoring can be expensive, and therefore can not be used extensively in most instances. However, a trained observer can quickly survey buffer zones for herbicide damage to vegetation, and, at relatively low cost compared to chemical analysis of water, verify the effectiveness of the buffer zone.

This element of the monitoring plan provides specific direction for site selection based on random selection of buffers to be surveyed, the procedures for plot selection and how to conduct the visual survey at each point, and the procedures for data analysis and reporting.

An important aspect of this strategy is familiarization of the observer with herbicide effects on vegetation. This can be accomplished by study of vegetation in and near the treatment area. Precautions to not represent insect or disease damage as herbicide damage are important.

The combination of the water quality monitoring done at a few locations and the more extensive survey of herbicide damage to buffer zone vegetation will provide managers of ROW on the Allegheny National Forest with a powerful tool. It will improve management decisions and will provide a basis for increasing the confidence of the public in the operations of these ROW.

## ELEMENTS IN A STRONG DATA COLLECTION PROGRAM

There are a number of elements common to successful scientific data collection programs. These are not mysterious at all, being in essence a restatement of the steps of the scientific process, couched in terms relevant to the thrust of this paper. These elements are described below, with examples developed earlier for research and the example for practice used to illustrate the element

*Describe the problem*

This step is crucial to success. Identification of the problem to be solved by this effort will help ensure that the process used is relevant to the question. In terms of the research examples used earlier, the problem was uncertainty about the effectiveness of buffers of various widths and how this might be influenced by vegetation density. In the problem from practice discussed earlier, the problem was to verify that the buffer zone strategy was achieving protection of water quality.

*Establish the specific question to be answered*

In research and as well in practice, this is the statement of the hypothesis, i.e., what is believed to be true. In the research example, the specific question was to establish the relationship between spray deposition and distance from the treatment zone, as influenced by treatment methods and vegetation density. In the example from practice, the specific question was, did the buffer zone strategy prevent herbicide from entering the stream in amounts that exceeded the water quality criterion for that chemical?

*Determine the specific data needed to answer the question*

It is very important to not take this step until the first two steps have been completed. There are far too many examples where decisions about data collection are made before decisions about the specific question have been established. In the research example, the specific data needed are a measure of herbicide deposition on an area basis, with these data being collected at different distances from the treatment area, etc. In the example from practice, the specific data needed are the concentration of herbicide in water at various times after the application, including after the first rainstorm.

*Establish the methods*

This is the step in which the specific procedures for data collection are established. It is crucial to the success of the effort. Inadequate methods will doom the entire effort to failure. In the research example, we used a dye to represent the herbicide, and by adding known amounts of it to the test spray mix, we were able to calculate the amount of herbicide represented by specific amounts of the dye. In the example from practice, the plan specifies the use of an automatic water sampler to collect individual samples in a predetermined schedule, with individual samples being selected for analysis. By compositing samples and by retaining the samples not submitted for analysis, it is possible to collect additional data if warranted. This is an important strategy in minimizing the cost of this effort.

*Develop the data analysis framework, and the basis for interpretation*

This is specifying how the data will be analyzed and interpreted. In the research example, the dye deposition was converted to equivalent amounts of herbicide based on the amount of herbicide represented by a given unit of dye. Then a regression analysis was used to establish the relationship among the variables. In the example from practice, the concentration of herbicide reported in water samples was compared to the water quality criterion for the specific chemical, and if the criterion was not exceeded, the buffer was determined to be achieving the water quality protection goal.

*Document what was done, and what was found*

This is the reporting process. Development of a report with enough detail to remove uncertainty about what was done and what was found is essential. Inevitably, you or others will want to revisit this matter, and lack of detail in reporting is certain to lead to uncertainty and confusion about what was done. Reporting in research and in practice is most likely to involve a technical report. In research it should be followed as well by a publication in an appropriate technical outlet.

*Publishing the results is important if this is possible*

Whether in research or practice, a publication of the effort in a peer reviewed, refereed outlet will increase the credibility of the effort, and equally important, increase the likelihood that it will be effectively archived where others can locate it in the future. Unpublished, internal reports are seen by very few people and have a short shelf-life. The effort to this point in either research or practice usually has been significant. Usually the results do not need to be proprietary, and the entire industry benefits by this sharing of information.

## CONCLUSION

Knowledge is crucial to good decisions. Programs of research and monitoring that produce relevant data are crucial to the development of better bases of knowledge. Having the data removes uncertainty, increases the likelihood of acceptance of the conclusions and will increase the quality of decisions relating to the siting, construction and management of rights-of-way.

Among reasonable people, data leads to better decisions. Even among unreasonable people, having the data greatly improves the chances of rational decisions.

## REFERENCES

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

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.

Norris, L.A. and P.M. Charlton. 1995. Determination of the effectiveness of herbicide buffer zones in protecting water quality. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-way Management. G. Jean Doucet, C. Segui and M. Giguere, eds. Hydro-Quebec, Montreal, Quebec, Canada. pp. 147–152.

Sheppard, S. 1989. Visual Simulation: A User's Guide for Architects, Engineers, and Planners. Van Nostrand Reinhold, New York.

USDA Forest Service. 1997. Vegetation management on electric utility rights-of-way. Final Environmental Impact Statement. USDA Forest Service, Allegheny National Forest, Warren, Pennsylvania.

### *BIOGRAPHICAL SKETCH*

***Logan A. Norris***

*Professor and Department Head, Department of Forest Science, Oregon State University, Corvallis, OR 97331, USA*

Logan Norris has a B.S. and M.S. in Forestry and Ph.D. in botany from Oregon State University. He has worked with the environmental fate and impact of herbicides in forests and on ROW since 1963, beginning with Bonneville Power Administration. Today this work is primarily through Environmental Consultants, Inc., Southampton, Pennsylvania, where he is on the Board of Governors.

# Preparing Implementation Plans for Federal Projects

**Patricia Patterson and David F. Jenkins**

A standard environmental condition attached to many certificates or permits from Federal agencies requires that an Implementation Plan be submitted to the regulatory agency. The Implementation Plan defines how and when the company will meet the environmental conditions of the certificate or permit. The Implementation Plan may be an important requirement for acquiring clearance from the agency to proceed with project construction. The level of detail and format of the Implementation Plan, as well as the company's internal scheduling considerations, will all influence the usefulness of the Implementation Plan for agency staff. This paper discusses factors affecting the development of an Implementation Plan and the type of information and level of detail to be included in a good Implementation Plan.

*Keywords*: Certificate, construction scheduling, environmental conditions, Implementation Plan, National Environmental Policy Act (NEPA), permit

## INTRODUCTION

The National Environmental Policy Act (NEPA) (US Government 1970a) requires Federal agencies with the primary responsibility for the environmental review of projects to comply with a stringent review process to assess potential environmental impacts (US Government 1970b). This review process can take well over 12 months (Council on Environmental Quality 1981) and can involve a multitude of parties, including Federal and state agencies, the company proposing the project (the company), and the various consultants, construction contractors, and affected landowners.

To accommodate the many variables associated with concurrent review of a proposed project, many agencies use a phased analysis and approval process to complete environmental review of a project. This has evolved into a procedure whereby the regulatory agency completes its analysis for the environmental document based on available information. The agency then places environmental conditions on the certificate or permit issued to the company. These environmental conditions require the company to implement certain mitigation activities and to provide additional information that was impractical or impossible for the company to provide as part of its original application. In theory, all data should have been available to the reviewing agency during the preparation of the environmental documents so the agency can meet its NEPA obligations. However, the company may have been unable to provide certain information, such as the results of field survey on a linear project (e.g., a pipeline project), if landowners would not grant the company right-of-entry onto their property to conduct the surveys. Therefore, the certificate or permit can include the environmental condition that the company conduct and/or complete the required surveys.

Typically, the environmental conditions will require that the company submit this additional information to the agency as a pre-construction filing (i.e., before the initiation of construction) and carry out certain mitigation activities during construction, restoration, and operation of the project to mitigate environmental impact. A mechanism used by regulatory agencies to evaluate if the company understands what information is required for the pre-construction filing of materials related to the environmental conditions and if the company understands the requirements for complying with mitigation measures included in or required by the certificate is to require the company to submit an Implementation Plan defining how the company will meet or comply with the environmental conditions.

An Implementation Plan, as discussed herein, is a document that defines how and when environmental conditions will be met and implemented before, during, and after construction. The Implementation Plan as described is basically a scope of work for complying with the environmental conditions of the certificate or permit.

A general format for an Implementation Plan is suggested below and addresses the typical concerns of many regulatory agencies. While different regulatory agencies may have different expectations, the following format provides information that is typically required by agencies for their review of post-certificate pre-construction filings.

## OBJECTIVES OF AN IMPLEMENTATION PLAN

It is important to understand what the agency staff expects from the Implementation Plan and how authorization to initiate construction (also known as construction clearance) will be provided, if required. In some cases, the agency may require that all environmental conditions be met for the entire project before any construction on the project can begin. In other cases (especially large linear projects, such as pipelines), the agency may authorize construction of segments of the project as pre-construction filing requirements are completed. In either case, it is often useful to consult with agency staff to determine if any specific format is required or recommended for a particular project. Agency staff may have established agency procedures that need to be met or preferences on how information is submitted to facilitate review.

However, in most instances, agency staff relies on the company to define the contents of the Implementation Plan. It is therefore important for the company to provide an Implementation Plan that clearly and succinctly addresses the environmental conditions of the certificate or permit and indicates when pre-construction submittals will occur. Many construction delays associated with delayed construction approvals from Federal agencies are the result of incomplete or late pre-construction filings from the company. This, in turn, may result in inadequate time for agency staff review before a required (or desired) construction start date.

Generally, the environmental conditions will require that the Implementation Plan is submitted shortly after issuance of the certificate or permit. The environmental conditions will sometimes require that a company describe how it will comply with the environmental conditions, when it will provide remaining information or final construction plans, and when construction will begin and end.

The Implementation Plan can result in several benefits. The development of the Implementation Plan requires that the company define the approach and institute the procedures that are needed to comply with the environmental conditions of the certificate or permit. The Implementation Plan, once submitted, allows the agency to plan for the allocation of sufficient staff or other resources to review and respond to pre-construction filings, issue construction clearance if necessary, and schedule construction inspections as needed to ensure full compliance with the agency's NEPA responsibilities. By providing the agency with the details of when information will be submitted and how activities will be carried out, the agency may be able to better schedule its resources, resulting in expeditious review and an on-time start of construction.

## CONTENTS OF AN IMPLEMENTATION PLAN

An Implementation Plan should provide a clear indication that the company fully understands the environmental conditions of the certificate or permit. It should provide enough information to assure the regulatory agency that its responsibilities under NEPA will be met with the pre-construction filing(s) and that the company will comply with the environmental conditions of the certificate or permit. An Implementation Plan should also provide a realistic schedule of when the pre-construction filing(s) will be submitted to the agency, when the company wishes the construction to begin, and how construction, restoration, and operation activities will comply with the environmental conditions of the certificate or permit.

Although any format could be used, the simplest format is to list and respond to each environmental condition. Providing the following information is important to making the Implementation Plan complete.

- Provide a concise description of how each environmental condition will be met. This includes the type of information that will be provided to the agency in pre-construction filings, how any outstanding studies will be conducted, what consultations will be undertaken, etc. As noted above, the Implementation Plan is essentially a scope of work for meeting the environmental conditions of the certificate or permit.
- Indicate when the outstanding pre-construction information will be submitted to the agency. This information may also be summarized in a table that identifies each environmental condition and the date when the material addressing each environmental condition will be or was submitted to the agency.
- Provide a detailed schedule showing the planned initiation of the major construction activities, such as clearing, grading, installation, cleanup, and restoration, for each project component (e.g., construction spread or facility).

## OTHER CONSIDERATIONS

The complexity and detail of an Implementation Plan is often affected by the size of the project, when construction will occur, and environmental conditions that can alternatively apply to the entire project or only to site-specific situations. Obviously, more effort would be required for a large project with a certificate or permit involving multiple environmental conditions. In addition, general and site-specific environmental conditions can often require additional consultation with or approvals from other agencies or land managers, the completion of additional environmental studies, or the preparation of detailed construction or restoration plans.

For example, a certificate or permit for a project may include numerous separate environmental conditions, some of which apply to the entire project and others that apply only to specific locations. Individual environmental conditions may also require the submittal of site-specific plans or the completion of environmental surveys (such as cultural resources or endangered and threatened species surveys) and agency approval of these plans and surveys before construction can begin. In addition, the certificate or permit may require the submittal of the Implementation Plan and the additional information before the agency grants final clearance to the company to construct the project.

If the project (or certain project components) will be constructed several months (or years) in the future, but the Implementation Plan must be submitted to the agency soon after issuance of the certificate or permit, the Implementation Plan would typically address the general environmental conditions, establish the schedule for the planned submittal of the additional remaining information, and define the anticipated schedule for project construction. When construction is finally imminent and construction clearance is required for this same project, it is advisable to consult with the agency staff to determine the best method of requesting construction clearance.

In cases where project construction is phased over time or in multiple construction spreads, it may benefit the company to prepare an updated Implementation Plan for those facilities that will be constructed at a later time which: 1) restates the responses to the general environmental conditions submitted previously (or the dates when this information was filed and when agency clearance was granted, if applicable), and 2) incorporates any additional site-specific information. If changes have been made to the original Implementation Plan, these changes may be summarized in a table or otherwise highlighted in the text for easy review and verification by agency staff.

Although agency staff may not require more than one Implementations Plan (one immediately following issuance of the certificate or permit and one [or more] immediately before facility construction of other facilities), submittal (or resubmittal) of all relevant information regarding the environmental condition at the time that construction clearance is desired can expedite agency review since all pertinent information is available in one place at one time. This is particularly important where project construction is phased in segments over a period of time, as discussed above, or in a number of construction spreads. The main benefit is that it allows agency staff to focus on construction clearance rather than assembling and verifying information submitted over a period of time to determine if all pre-construction conditions have been met.

Finally, it is crucial to allow agency staff adequate time for review of the Implementation Plan, particularly if it is a component of the company's request for clearance to begin construction. It is also advantageous for the company to file the information with the agency as originally scheduled in the Implementation Plan so that agency staff are available for necessary review.

## SUMMARY

A good Implementation Plan can serve several purposes. First and foremost, it can assist the company in devising a strategy and a schedule for complying with the environmental conditions of a certificate or permit. Second, it assures agency staff that the environmental conditions will be met and allows the agency to schedule staff resources for any additional review of the project or its components. An Implementation Plan that is concise and complete can expedite agency review, if construction clearance is required by the agency before the company can begin construction.

## REFERENCES

US Government. 1970a. Pub. L. No. 91-190 (1970), as amended by Pub. L. No. 94-52 (1975), and Pub. L. No. 94-83 (1975) (codified as amended at 42 USC § 4321-47).

US Government. 1970b. NEPA § 102(2)(C), 42 U.S.C. § 4332 (2)(C).

Council on Environmental Quality. 1981. Forty most asked questions concerning CEQ's National Environmental Policy Act regulations. 46 Fed Reg. 18,026, 18,031.

---

## *BIOGRAPHICAL SKETCHES*

***Patricia Patterson***

*Foster Wheeler Environmental Corporation, 470 Atlantic Avenue, Boston, Massachusetts 02210-2208, USA*

Patricia Patterson is a Senior Environmental Planner at Foster Wheeler Environmental Corporation with over 12 years of experience in the siting, licensing, and impact assessment of linear transmission and power generation projects.

***David F. Jenkins***

*Foster Wheeler Environmental Corporation, 470 Atlantic Avenue, Boston, Massachusetts 02210-2208, USA*

David F. Jenkins is a Program Manager at Foster Wheeler Environmental Corporation and has over 19 years of experience in siting, impact assessment, and Federal and state licensing of energy projects.

# An Ounce of Prevention: Environmental Training for Linear Projects

**Daniel C. Pearson and Richard D. Williams**

Today's regulatory climate along with the ever increasing number of environmental sensitivities makes environmental training an important component of any successful construction project. This is especially true for construction of linear right-of-way projects which tend to traverse long distances and may encounter large numbers of sensitive resources. Use of environmental training for operation and maintenance activities is also becoming a necessary component of a company's training regimen as agencies and the public are becoming increasingly concerned about sensitive environmental resources. A successful environmental training program can avoid project delays, civil or criminal fines and penalties and can be used to demonstrate corporate environmental responsibility. Avoiding impacts to sensitive resources can generally be successfully avoided with a well-designed and executed environmental training program.

*Keywords*: Environmental training, environmental impact, sensitive resources, rights-of-way, linear facilities, construction, environmental laws, environmental awareness, environmental compliance

## INTRODUCTION

Environmental training of construction personnel has become increasingly important to the successful permitting and construction of linear rights-of-way projects. There are three primary reasons why comprehensive environmental training is important: (1) increasing numbers of sensitive and legally-protected environmental resources; (2) increased regulatory and public scrutiny of activities that may adversely affect these resources; and (3) the extensive area traversed by most linear rights-of-way, which increases the potential of encountering a sensitive resource. Additionally, there is increasing concern for the effects of operating and maintaining linear facilities on sensitive resources, particularly for those that acquired legal protection (e.g., a species being added to the federal list of endangered species) after a project has been permitted and constructed.

### Resource protection issues

The number of sensitive and legally-protected environmental resources that project proponents must address continues to grow. For example, nearly 1,000 plant and animal species have been placed on the list of threatened and endangered species under provisions of the federal Endangered Species Act of 1973, as amended (ESA) (Thelander 1994). Many individual states also provide additional legal protection for plants and animals through various laws and regulations. For example, the state of California, with arguably some of the most stringent environmental laws among the fifty states, provides protection to over 300 species under provisions of the California Endangered Species Act (California Natural Diversity Data Base 1996), state legislation enacted in 1984 and comparable in many respects to the ESA (West's Codes 1995).

In addition to species that are already listed, there are a large number of "candidate" species that are under active consideration for addition to the federal and/or various state endangered species lists. However, federal policy on candidate species was recently revised to invoke a more restrictive definition of what constitutes a candidate for listing under the ESA (Department of the Interior 1996). While this change in policy reduced the number of candidate species, the former candidates for listing are still considered to be sensitive and are often subject to considerable regulatory and public scrutiny during the permitting process.

Many other sensitive resources receive legal protection under a variety of federal and state laws. Among these, particular attention is often paid to the potential effects of linear projects on archaeological/cultural resources and the protection of wetlands and other sensitive habitats. Areas of archaeological significance (e.g., Native American sites) are considered sensitive because of their finite number and distribution, historical and scientific value, and their cultural and religious significance to many Native American people. Actions that may affect wetlands also receive significant scrutiny because of their rapid decline in acreage and distribution - it is estimated that 75% of the nation's historical wetlands have been lost, in California, 95% of historical wetlands have been lost (Thelander 1994) - their value in supporting diverse populations of plants and wildlife, their role in filtering toxic materials from water supplies, and many other intrinsic values.

### Environmental regulation and compliance concerns

A variety of federal, state, and local environmental laws and regulations apply to the construction of linear facilities. Of the federal laws, the most frequently invoked are probably the ESA, Federal Water Pollution Control Act (perhaps better known as the Clean Water Act – P.L. 92-500), Migratory Bird Treaty Act of 1916 (Convention for the Protection of Migratory Birds, 39 Stat. 1702), Eagle Protection Act (P.L. 87-884), National Environmental Policy Act (P.L. 91-190) and National Historic Preservation Act of 1966 (P.L. 89-665). Violations of these laws can result in substantial fines, often regardless of intent or prior knowledge of applicable regulations on the part of the individuals involved. For example, a violation of the ESA can result in civil and criminal penalties of up to $50,000 in fines and one year in prison for each violation. A knowing violation of Section 404 of the Clean Water Act, such as unauthorized disturbance to a wetland, could result in a fine of $25,000 per day, imprisonment of up to one year, and required remediation.

Companies conducting work regulated by a federal, state, or local permitting authority must be particularly concerned about adhering to project specific conditions and restrictions for the protection of sensitive environmental resources as defined by their permit. A company not complying with the requirements of their permit risks costly delays in construction, substantial fines, criminal action, and potential loss of permits and licenses for the project. For example, the Federal Regulatory Energy Commission (FERC) recommended a gas pipeline company be fined $37 million for disturbing archaeological sites during the construction of a pipeline (Engineering News Record 1991). Other instances where lack of environmental training has resulted in problems, a California electric utility is being sued for damage to archaeological resources resulting from access road maintenance in a state park; another California utility was required to buy habitat as a result of habitat lost as a result of the installation of a non-regulated transmission line; and, a state water authority was caught by the California Department of Fish and Game doing repair work to a state-operated water canal that resulted in loss of endangered species habitat. Most acts of non-compliance that result in unauthorized disturbance to a sensitive resource can be avoided.

### Risk potential of linear projects

Linear rights-of-way can be divided into four primary categories based on the type of facilities they contain: (1) electric power lines and communication lines; (2) transportation systems (highways, railroads, mass-transit systems); (3) pipelines (gas, liquids, slurry); and (4) open water conveyances (canals, irrigation ditches). The land dedicated to these rights-of-ways is extensive. One estimate from the late 1970s suggested that approximately 13.8 million ha or nearly 2% of the land in the conterminous 48 states was already dedicated to linear rights-of-way (Asplundh Environmental Services 1978). The land area dedicated to these facilities has undoubtedly increased substantially since these earlier estimates.

Rights-of-way, by nature of their linear configuration, traverse substantial distances and thereby increase the risk of encountering one or more sensitive resources along their length. The fact that construction is often accomplished by multiple crews operating simultaneously at scattered locations within or along a right-of-way increases the difficulty in ensuring full compliance with the environmental protection measures mandated by the project permit requirements. A thorough environmental education program provided to every project worker is the best way to ensure that each individual understands his/her compliance responsibilities and accountability within the context of the entire project.

## APPLICABILITY, ACCOUNTABILITY AND COMPANY COMMITMENT

### Who needs training?

Corporate officers typically bear ultimate responsibility for the actions of their employees, particularly when culpability is reinforced by repeated offenses that demonstrate a blatant disregard for resource sensitivity. While they may not need the training themselves, corporate officers should be aware that training programs within the company exist and they must support their objectives. Compliance with certain laws (e.g., federal Migratory Bird Treaty Act) can also be the responsibility of the individual field worker whose actions violate applicable statutes. As a result, the safest approach is to provide environmental training to all individuals with direct involvement on a project, from heavy equipment operators to construction foremen to on-site management. In a case exemplifying why this top to bottom training approach is best, operation and maintenance activities by an electric utility crew on an existing transmission line inadvertently removed the habitat of an endangered bird species in southern California, individuals who authorized the work, not necessarily the individuals who performed the work, would have been subject to prosecution had the company not agreed to mitigating the lost habitat.

### Which projects need environmental training?

Construction projects, especially those in known sensitive areas, should proceed only after a comprehensive environmental training program has been developed and presented to all project personnel. The need for a training program and, in some cases, specific training requirements are clearly established by the permitting agencies within the final permits and licenses. Specific training requirements may include measures to control trash and litter, establish speed limits within construction zones, work schedule constraints and restrictions on off-road travel. In addition to conditions mandated by established laws for resource protection or by a project license, training programs should incorporate additional safeguards that the company considers to be ecologically responsible and in the best interests of the environment and the company. Voluntary efforts to protect and enhance the environment can often provide tremendous public relations benefits at little or no additional cost. Consistent demonstrations of "good faith efforts" by a company can pay dividends during future negotiations with permitting agencies or when an inadvertent act of non-compliance occurs.

Training for operation and maintenance activities can be as important (if not more so) as new construction training. For example, a sensitive resource potentially affected by operation and maintenance activities may receive legal protection subsequent to the issuance of the project license. Company management and field personnel directly involved with operation and maintenance activities may not be aware of the legal obligations resulting from new legislation (e.g., the inclusion of a new species on the endangered species list). Although a company may feel less obligated to conduct environmental training for operation and maintenance activities that have been ongoing for a number of years with no apparent impact, the penalty for impacting a protected resource may be as severe as if incurred during construction of the project.

### Workable performance standards

Measurable and quantifiable performance standards should be identified and monitored to document the success of a training program. These standards may be initiated by the permitting agency (e.g., a requirement for independent monitors to ensure compliance) or by the developer (e.g., performance clauses incorporated into construction contracts to protect a company from noncompliance by sub-contractors). In all cases, a company should retain thorough documentation of its training program, including a procedure for tracking completion of the training program by all project personnel.

### Company commitment

A genuine company-wide commitment to training and responsible construction practices is the key to the success of a company's environmental protection program. This commitment can be initiated by the company's officers, or by lower level personnel with full endorsement by upper management. Regardless of where the commitment originates, support by the company's top management is critical to the success of any program. The absence of upper level support is easily sensed by field personnel who will respond in-kind. Field personnel should be encouraged to treat environmental training as an integral part of their job rather than a unfortunate distraction.

## DEVELOPING AN EFFECTIVE PROGRAM

### Topics to address

At a minimum, training must address the known sensitive and legally protected resources occurring within a project area. In some situations, it is appropriate and advisable to also include sensitive resources that have the potential to occur in the area, but whose presence has not been confirmed. This is especially important for operation and maintenance activities where only limited pre-construction surveys were performed and/or the likelihood that a protected species or other sensitive resource occurs in the project area has increased since construction was completed (e.g., the new listing of a species that may occur in the area). Issues typically addressed in environmental training programs include: (1) sensitive plants and animals, particularly threatened and endangered species, raptors and other nesting birds; (2) sensitive habitats, including wetlands (e.g., streams, rivers, riparian zones, vernal pools), native grasslands and meadows; and, (3) cultural resources (i.e., historical, pre-historical, and paleontological).

### Medium selection

Selecting the proper medium for presenting the training program to the workers is dependent on a number of factors, including the type of project activity (i.e., new construction, operation, or maintenance activity) and training location (i.e., a remote construction site, field office, corporate office). For example, training at a construction site may entail a simple "tailboard" session with or without written materials and handouts, while office or classroom sessions allow for the use of a variety of written and audio-visual materials. The most successful programs combine the elements of both classroom and on-site training including videos, slides, and written materials such as wallet cards, manuals, brochures, and posters. The advantages and disadvantages of each of these training elements are summarized in Table 1.

**Table 1. Advantages and disadvantages of various training media**

| Training medium | Advantages | Disadvantages |
|---|---|---|
| Training manuals | Provides lasting reference source. Best suited for on-going training needs such as operation and maintenance activities. Can be readily updated if designed appropriately. | Can be costly and time-consuming to develop. |
| Wallet cards | Provides ready reference source for field personnel. Compact, easy and inexpensive to prepare. Provides telephone numbers of immediate first contacts if problems develop or questions arise. | Lack of extensive information. |
| Brochures | Provides summary of essential elements of training program. | Lacks sufficient detail to supplant training program. |
| Videos | Can be used when numerous training sessions are required and time for trainers is constrained or limited. Provides greater opportunities to maintain interest of field personnel with interesting footage. | Can be costly to develop ($1,000–2,000/minute of finished product). May not provide for opportunity for question and answer exchange between trainer and field personnel. May not work in some field training situations. Difficult to update. |
| Slide presentation | Provides for one-on-one interaction between trainer and field personnel, enhancing the opportunity for question and answer. Provides increased opportunity to maintain interest of field personnel with interesting footage. | Can be labor intensive if many training sessions are envisioned. |
| Posters | Provides constant reminder to field personnel of their obligations and responsibilities. Can be relatively long-lived. Relatively inexpensive to produce. | Lack of interaction between personnel and trainer. May not be read by personnel. |

### Documentation

An important aspect of any training program, but particularly new construction training, is a signed statement from project personnel that they have received the training, they understand the information conveyed to them, and they agree to abide by the conditions and restrictions contained therein. In some cases, the threat of disciplinary action or even termination of employment may be added to motivate compliance. These options, however, may be precluded when union employees are protected from such actions by existing labor contracts. Nevertheless, requiring an employee's signature indicates that the company takes the training program seriously and expects its employees to do the same.

### Training for subcontractors

In addition to training company employees, training should also be required of subcontractors, particularly if they will be doing work in environmentally sensitive areas. As indicated above, it is also important to include performance clauses in contracts with subcontractors to provide a legal obligation to follow the requirements set forth in the environmental training program; primarily because permitting agencies require companies to assume responsibility for all project actions, including those performed by subcontractors. The use of performance clauses provides companies with a legal mechanism for imposing financial penalties on a subcontractor for non-compliance, or to void a contract.

### Refresher courses

Most construction projects are of short enough duration that environmental training provided at the beginning of the construction project is generally adequate to ensure that all workers are knowledgeable of what is required of them. This is particularly true if on-site monitors are present to reinforce training material and to answer questions that may come up.

For ongoing operation and maintenance activities, refresher training, usually on an annual or bi-annual basis, is recommended. Refresher training not only serves to reinforce training material in minds of workers, it also provides the opportunity to update training with new developments in legislation and/or regulations, adds to the list of sensitivities that must be protected and avoided, provides training to new employees or intra-company transfers, and adds to a sense of company commitment to the training program.

### Regulatory agency involvement and approval

The level to which regulatory agencies are involved in the environmental training program depends on whether the training program is proactive (i.e., voluntary) or reactive (i.e., required). Generally, for new construction or operation and maintenance activities that may require an agency permit, the agencies will require some type of environmental training program if the potential exists for harm to protected environmental resources as a result of the proposed action. If environmental training is required, the agencies will typically detail the material they want to have covered in the environmental training. The agencies will generally leave the methods of training up to the applicant, although they will generally require that the training program be submitted to them for final approval before implementation. If the company implementing the training wants more control over the training (i.e., determining the content, medium, etc.), they can recommend environmental training up front as part of project mitigation. The agencies will still ask for final review and approval of the training program, but for those project proponents interested in helping to control the pace and direction of their project, offering environmental training initially (i.e., by being proactive) will likely have greater success with their overall project. From this perspective, being proactive with respect to environmental training can be advantageous.

Environmental training for operation and maintenance activities is generally proactive (voluntary) since many linear projects were built before many environmental laws were enacted or operation and maintenance falls under the guise of non-regulated activities. Proactive environmental training has many advantages, including: (1) helping a company maintain compliance with existing laws and regulations; (2) helping establish a record of good corporate responsibility and stewardship; and, (3) helping in future dealings with agencies, environmental groups and the general public.

Involving the regulatory agencies to develop some training material can be helpful in demonstrating a company's commitment to the program, and in obtaining agency endorsement of course goals, content and approach.

### Quality assurance

Assuring the effectiveness of an environmental training program is an important aspect of the program, and should be developed in conjunction with workable performance standards. Not only does it help identify strengths and weaknesses in the current program, it helps in improving future programs, and can also be used to demonstrate compliance with agency guidelines and conditions. In addition to on-site monitor's notes and observations, the on-site monitor or trainer can spot check to see if any conditions contrary to that advanced in the training exist, and identify circumstances concerning these contrary conditions. Feedback from workers can be solicited to see if they are encountering any problems or if they have questions concerning what is expected of them. At the same time, if workers were provided certain training materials that they were instructed to have readily available for use, such as wallet cards, the on-site monitor or trainer can determine if the workers are in possession of this material.

## SUMMARY

### Pros and cons of environmental training

In evaluating a number of environmental training programs, it is difficult to find any reason for a company building a new linear right-of-way project, and/or engaged in long-term operation and maintenance not to have some type of environmental training program. The sole objection for not having such a program may be cost. However, when one considers the adverse consequences of no, or an inadequate, training program, it does not appear to be justified.

## REFERENCES

Asplundh Environmental Services. 1978. Benefit analysis — use of 2,4,5-T for vegetation management on rights-of-way. Asplundh Environmental Services. Willow Grove, Pennsylvania. 44 pp.

California Natural Diversity Data Base. 1996. California Natural Heritage Division — California Department of Fish and Game — List of Rare, Threatened or Endangered Species in California. Sacramento, California.

Department of the Interior. 1996. Federal Register. Volume 61, Number 235, pp. 64481–64485.

Engineering News Record. 1991. Alabama Seeks Damages. Volume 226, Number 1.

Littell, R. 1992. Endangered and Other Protected Species: Federal Law and Regulation. Bureau of National Affairs, Inc. Washington, D.C. 185 pp.

Thelander, C.G. 1994. Life on the Edge: A Guide to California's Endangered Natural Resources — Wildlife. BioSystems Books, Santa Cruz, California. 550 pp.

West's Codes. 1995. West's Annotated California Codes. California Fish and Game Code. Sections 2050–2100. West Publishing Company, St Paul, Minnesota.

## *BIOGRAPHICAL SKETCHES*

***Daniel C. Pearson***

*Senior Biologist, Southern California Edison, P.O. Box 800, Rosemead, CA 91770, USA*

Daniel C. Pearson is a Certified Wildlife Biologist and Professional Wetland Scientist with over 20 years of professional experience as a biologist, including 19 years with Southern California Edison. His experience includes project licensing and permitting, project mitigation and environmental training. He has developed award-winning training programs for Edison that have been adopted by other utilities, resource agencies, other state agencies and other developers. His interests include environmental policy, endangered species and environmental education. He is currently Project Manager of the Land Services Group within Edison's Environmental Affairs Division.

***Richard D. Williams***

*Environmental Consultant, Williams and Associates, 103 Tidepool Court, Folsom, CA 95630, USA*

Richard D. Williams is a Certified Wildlife Biologist and environmental consultant with 18 years of professional experience including 14 years as a biologist within the gas and electric utility industry. His technical interests include environmental policy, endangered species, avian ecology, and environmental education. Mr. Williams currently serves on the governing council of The Wildlife Society, an international association of wildlife professionals.

# A Review of the Public Consultation Program Used in the Development of Water Supply Facilities. A Case Study

**Peter G. Prier**

The purpose of this paper is to review the public consultation program used in the development of water supply facilities in terms of how and why it evolved over time and to evaluate its success. The consultation program techniques are described with specific reference to changes in the program in response to opposition from an organized group of directly affected landowners. Input from the landowners' association resulted in changes to the consultation program design and schedule. Decision-making over the course of the program shifted from the proponent to a joint committee that included landowner representatives. An evaluation of the success of the program concluded that the program was successful in building a more trusting relationship between the proponent and the opposition. Development of a public consultation program should be early in the project planning process, should maximize the opportunities to receive input and should consider joint decision-making wherever possible.

*Keywords:* Public Consultation, water pipeline, joint decision-making, participation.

## INTRODUCTION

The purpose of this paper is to outline: (1) the evolution of the public consultation program implemented in the planning and construction of water supply facilities; (2) how and why the program evolved from single source to joint decision-making; (3) an evaluation of the program's success based on opportunities, flexibility and opposition influences on decision-making; and (4) recommendations for the development of a public consultation program.

This paper is approached from the perspective of a practitioner, not an administrator or academic. My primary focus in the area of public consultation is in what works, how it works and the lessons learned that can be applied to development of future public consultation programs. The importance of building a relationship of trust between proponents and opposition groups cannot be overemphasized.

## BACKGROUND

The Ontario Clean Water Agency (OCWA) was established in 1993 to carry on the activities of the Ontario Ministry of Environment and Energy (OMOEE) with respect to the project management, administration and operation of water supply-distribution and sewage collection-treatment facilities in the Province of Ontario. One of the systems which the OCWA owns and operates is the Lake Huron Water Supply System, part of which is the 47.2 km long, 1200 mm (48 in) pipeline that extends from Lake Huron to just north of London, Ontario. The system serves London, Ontario and thirteen small communities along the pipeline route.

The pipeline was completed in 1967 and has been in continuous daily operation since. As a result of ruptures in the pipeline in 1983 and 1988, engineering investigations identified three sections of the pipeline that required twinning. Consequently, the OMOEE, in 1991, initiated a Class Environmental Assessment (Class EA) under the Provincial Environmental Assessment Act (EAA) for the twinning of approximately 19 km of the existing pipeline (the project). The OCWA, in 1995, completed the Class EA initiated by the OMOEE. The pipeline was constructed and put in service by the end of 1996.

Class EA public consultation requirements are minimal. However, as a result of opposition to the project during and after preparation of the Class EA, a much more comprehensive consultation program was developed for the detailed design and construction phases of the project's development. The comprehensive consultation program incorporated more frequent communication opportunities and by necessity, evolved in response to opposition input.

The main group opposed to the project were landowners directly affected by the pipeline. Approximately 50% of directly-affected landowners formed the Lake Huron Pipeline Landowners Association (LHPLA) and retained legal counsel. Throughout the project, the LHPLA were virtually the only opposition actively involved during planning and construction.

The primary concerns of the LHPLA were related to negative effects of the project on soil and crop productivity, water wells along the route and financial compensation for disturbances and crop loss. The LHPLA also wanted reimbursement for legal fees, the members' time involvement reviewing documents and the LHPLA on-going participation through project completion and operations.

## LEGISLATED CONSULTATION PROGRAM. REQUIREMENTS AND RESULTS

Provisions under the Ontario EAA allow for the preparation of a Class EA. This type of EA follows a planning process used for a group of projects which:
- are relatively small in scale;
- recur frequently;
- have a generally predictable range of environmental effects; and
- which have relatively minor, environmental significance.

A clause within the Class EA planning process provides for a "bump-up" to a more detailed and comprehensive planning process when the environmental significance of a project is of "such proportion that the procedures for environmental assessment provided for under the Class EA process are not sufficient, and that an individual environmental assessment is required" (Municipal Engineers Association 1993). If a Class EA is "bumped up" to an individual EA, potential exists for a quasi-judicial public hearing and for pre-hearing participant funding.

The Class EA planning process for the project required consultation with review agencies and the public once during the planning process and that the Environmental Study Report must be publicly reviewed. The nature, frequency and usefulness of consultation techniques is not specified in the Class EA, it is a self-regulating process.

The legislated consultation program failed to achieve the support of the LHPLA. They requested a "bump-up" of the Class EA. This request signalled both a failure of the Class EA consultation process to win support from the opposition and the LHPLA's desire to shift the decision-making authority from the OCWA to the political forum and ultimately a legal or other regulatory authority. The bump-up request was denied by the political system, but on the condition that a more comprehensive consultation program, proposed by OCWA, be implemented.

## NON-LEGISLATED CONSULTATION PROGRAM DESIGN

Development of a public consultation program requires that one understand why opposition to a noxious or unwanted facility occurs. Generally opposition results from five principal concerns of the potentially affected public (Armour 1987) as follows:
1. inequities in the distribution of costs and benefits;
2. the stigma of an unwanted facility;
3. perceived risks;
4. feelings of loss of control over forces affecting the quality of one's life and community; and,
5. loss of trust in proponents and regulators.

The LHPLA opposition to the project focused on points one (1), four (4) and five (5), as noted above. Perceived inequities in the distribution of financial costs and benefits were offset during the negotiations that became part of the consultation program. The consultation program was designed in recognition of the need to reduce LHPLA perceptions of loss of control and to build a more trusting relationship with the OCWA. In order to build a relationship of trust, communication, opportunity and flexibility are the crucial elements that ultimately determine the success of a public consultation program (Law and Hartig 1993). These principles were incorporated into the consultation program using a variety of consultation techniques.

Communication among participants often comes too little, too late and is usually one way with many participation programs. In hindsight, it is apparent the first three years of the project were a good example of being too little, too late and often one way. Consequently, the more comprehensive program incorporated the following consultation techniques to ensure early, frequent, two-way communications: personal interviews; workshops; and a landowner relations program.

The techniques used provided frequent opportunities for those most interested to be kept informed as well as actively involved in the project's decision-making. Flexibility was not directly incorporated into the program when it was developed. Instead, the program became flexible as the program components were implemented. The open communication lines and frequent opportunities for involvement fostered a more trusting relationship between OCWA and the landowners that resulted in easier acceptance of differing views such as scheduling of meetings, the frequency, and design of questionnaires and workshop formats.

Negotiations and a joint decision-making committee were not part of the consultation program design. These were added as the program was implemented.

## THE EVOLUTION OF CONSULTATION TECHNIQUES

Table 1 outlines the project activities, consultation techniques, and decision-making authority that framed the consultation program. Project commencement to completion spanned a five-year period. During that period, public consultation evolved from "non-participation" to a degree of citizen power, as described by Arnstein's Ladder of Citizen Participation (1969); the remainder of this section describes how and why the consultation techniques changed.

The LHPLA raised the profile of their cause before the OCWA could implement the more comprehensive consultation program. They did this, after denial of the bump-up request, through the media by recognizing that radical, extreme behaviour makes good press. However, public consultation in the media is not the appropriate forum for meaningful information exchange or building trust. The local media coverage did, nonetheless, shift decision-making authority towards the LHPLA due to political pressure.

The OCWA response to the negative media, included provision of funding to LHPLA to hire consultants, immediate scheduling of workshops in consultation with the LHPLA and including the LHPLA in the actual questionnaire design and interviewing process. These concessions by the OCWA to the landowners represented a step towards building a more trusting relationship and increasing the degree of their influence in the decision-making process.

Another step forward in the trust building process occurred through negotiation. Negotiations were added to the consultation program after the interviews, workshops and meetings, when it became apparent to all parties that substantially increased environmental mitigation measures were going to be very, costly. Consequently, negotiations to reach a mutually acceptable set of feasible mitigation measures took place. The negotiations consisted of the OCWA staff, consultants, lawyers and the landowners association in approximately five all-day meetings. These were primarily bargaining sessions where environmental decisions were made, consistent with the model of environmental decision-making and the trading of political concessions (Sewell and O'Riordan 1976). The process of negotiation also resulted in steps forward in trust between the OCWA and the landowners.

The negotiations concluded with the signing of a Letter of Undertaking (LOU), jointly by the OCWA and the LHPLA. The LOU included 16 pages of jointly agreed to provisions, one of which was a Joint Committee (JC) of OCWA and LHPLA representatives. The JC was an additional consultation technique added at the request of the LHPLA. The JC terms of reference were to meet regularly throughout construction to identify areas of concern and their resolution. The JC met formally once a month during the six-month construction period. Informally, LHPLA representatives on the JC discussed issues with on site contract inspection staff on a once a week and sometimes more frequent schedule. Creation of the JC and its' joint decision-making nature was a positive step forward from the landowners perspective because they felt they were being listened to, and were involved in decision-making.

The cumulative effect of the increased communications and joint decision-making between the LHPLA and the OCWA was positive. Construction and implementation of mitigation measures proceeded smoothly. This was fortunate since the relationship of trust was tested when bad weather in the fall of 1996 resulted in non-completion of some of the mitigation measures.

**Table 1. Project activities, consultation techniques and decision-making authority**

| Project stage | Project activity | Consultation technique | Decision-making authority |
|---|---|---|---|
| Planning | Project is a Class EA | None (OCWA) | OCWA |
| | Prepare Environmental Study Report (ESR) | Public Meeting and Newsletter (OCWA) | OCWA |
| | Distribute ESR for Review | Review and Comment on ESR (OCWA) | OCWA |
| Report Review | Brief Minister | Request "Bump-up" (Landowner Association (LA)) | Minister of Environment |
| | Commence Detailed Design | Involve Local Media (LA) | Politicians |
| Design | Detailed Design | Landowner Interviews | (OCWA/LA)OCWA/LA |
| | Detailed Design | Landowner Workshops (OCWA/LA) | OCWA/LA |
| | | Negotiations (LA/OCWA) | LA/OCWA |
| Construction | Pre-construction | Landowner Interviews (OCWA/LA) | LA |
| | Construction | Landowner Relations Program (OCWA/LA) | OCWA/LA |
| | Construction | Independent Inspection (LA) | LA |
| | Construction | Joint Committee (LA) | LA/OCWA |
| | Clean-up | Negotiations (LA/OCWA) | LA/OCWA |

Non-completion of the project in fall 1996 meant that additional mitigation measures would be required. A decision as to what those measures should be led to some deterioration of the "trust" relationship because communication frequency within the JC decreased. However, recognition by both parties in the course of a series of meetings that non-completion was caused by circumstances beyond human control, led to some restoration of the trust relationship. The LHPLA had input and a final say in what some of the mitigation measures would be.

## EVALUATION OF THE CONSULTATION PROGRAM

The success of the consultation program has been evaluated by the author based on the "outcomes" (the extent to which the objectives were achieved), the "process" (the degree to which program techniques were successfully employed), and "attitudes" (the degree to which attitudes of those involved were positively or negatively affected).

The evaluation indicators (adapted from Sewell and Phillips 1979) and the author's assessment of the program success are listed in Table 2.

The goal of the comprehensive consultation program was to build a relationship of trust with the LHPLA. This required more frequent communications, more opportunities and that flexibility be considered in whether the program was successful. Based on the indicators used to evaluate the program, it is considered to have been successful. The reasons for this include less opposition as the program was implemented, greater involvement of the LHPLA in decision-making, an increase in trust between the OCWA and the LHPLA and changed LHPLA perceptions of their involvement.

**Table 2. Consultation program success**

| Indicator | Degree of program success or failure |
|---|---|
| Level of resistance | Decrease over time; partially successful |
| Changes in program caused by opposition feedback | Changes implemented to type of consultations, scheduling and mitigation techniques |
| Changes beyond the legislated requirements and frequency of communications | Program techniques successfully employed, exceeded legislated requirements, frequency of communications increased |
| Degree to which opposition influenced group decisions | Mitigation measures were added, modified, rejected or approved by landowners |
| Changes in self perception of committee representatives | Changes in attitudes of some committee members and perception of their involvement |

## CONCLUSIONS AND RECOMMENDATIONS

The consultation program used in the development of the water pipeline evolved over time. This evolution was driven firstly, by opposition to the project. The opposition group used the political system and the media to force changes in the consultation program. Secondly, the consultation program evolved as a result of negotiations. The lessons learned from this evolution are listed below:

1. Develop the consultation program early in the planning process but be flexible in its subsequent implementation.
2. Maximize the opportunities to receive input.
3. Consider joint committees for decision-making.
4. Ensure there is a mechanism for, and continuity of consultation throughout the planning, construction and monitoring phases of project development.
5. To the largest extent possible, use input received in decision-making.

## ACKNOWLEDGEMENTS

The author wishes to thank the staff of the Ontario Clean Water Agency (R. Dhillon, M. Looby and J. Carter), M.M. Dillon (D. Soper, B. Prouse, and H. Grund) and Ecological Services (R. Rowland, E. Mozuraitis) and the landowners involved in the consultation program, whose support and assistance were invaluable in successfully completing the project.

## REFERENCES

Class Environmental Assessment for Municipal Water and Wastewater Project. 1993. Municipal Engineers Association.

Armour, A. 1987. Report to the siting process task force on low level radioactive waste disposal: Socially responsive impact management — A discussion paper. Energy Mines and Resources Canada.

Arnstein, S. 1969. Eight rings on the ladder of citizen participation. Journal of the American Institute of Planners, 35: 216–224.

Law, N. and J. Hartig. 1993. Public participation in Great Lakes Remedial Action Plans. Plan Canada, March, pp. 31–35.

Sewell, W. and S. Phillips. 1979. Models for the evaluation of public participation programmes. Natural Resources Journal, 19: 337–358.

Sewell, W.R.D. and T. O'Riordan. 1976. The culture of participation in environmental decision-making. Natural Resources Journal, 16: 1–21.

## *BIOGRAPHICAL SKETCH*

***Peter G. Prier***

*Ecological Services for Planning Ltd., 361 Southgate Drive, Guelph, Ontario, Canada N1G 3M5*

Mr. Prier is one of the Principals of the Ecological Services Group of Companies. He is responsible for environmental management of facilities development. His primary areas of interest are in the planning construction and operation/maintenance phases of linear facilities development. He is a Bachelor of Science in Resources Management, honours graduate of the University of Guelph. He was responsible for the development of the modified consultation program and protection plan for the development of the water pipeline facilities.

# Life-Cycle Analysis for Transmission Line Design

**Joel M. Rinebold and Louise F. Mango**

Life-cycle analysis, incorporating both traditional costs and environmental considerations, is gaining increasing recognition as an important decision-making tool in the evaluation of utility projects and as a key element of future environmental management programs. In this study of electric transmission options, life-cycle costs, consisting of all capital and operating costs, are assessed for seven single-circuit overhead line configurations, eight double-circuit overhead line configurations, seven single-circuit underground line configurations, and nine double-circuit underground line configurations. All life-cycle costs are unit based for each five-mile segment of construction and are broken out between fixed construction costs and 35-year life-cycle costs. Typical electric and magnetic field levels also are assessed for each line configuration. Fixed variables include load and operating conditions, structure and conductor types, and cost factors in 1995 dollars. Environmental life-cycle costs associated with the development and operation of typical overhead or underground electric transmission lines are identified and discussed, but could not be quantified and included in cost assessments. Methods for evaluating and comparing such costs, either quantitatively or qualitatively, are assessed, and recommendations are made for future use in identifying environmental life-cycle costs for transmission projects. This life-cycle information provides a benchmark that will assist project managers, regulators, and community leaders in the preliminary identification and comparison of transmission line design, least-cost options, right-of-way management, environmental costs, and low electric and magnetic field alternatives.

*Keywords*: Life-cycle cost comparison, electric transmission lines, environmental life-cycle costs, underground vs. overhead transmission analysis

## INTRODUCTION

In late 1994, pursuant to Connecticut Public Act 94-176, entitled "An Act Concerning Life-cycle Cost Analyses and Certain Electric Facilities", the Connecticut Siting Council (Council) initiated an investigation of the comparative life-cycle costs of both overhead and underground electric transmission lines. As used in this investigation, "life-cycle costs" refer to the sum of all fixed costs of construction and operating costs that can be calculated in 1995 dollars for the development and operation of a specific transmission line over a 35-year operational life. The fixed costs of construction include civil work, materials, terminal costs, regulatory and permit fees, environmental studies, engineering and administration, and a contingency of 15%. Operating costs include calculated transmission line losses and maintenance costs. The analyses also considered relative reliability, constraints concerning access and construction, potential impacts to the environment, and compatibility with the existing electric supply system.

After discussion and interviews with utility representatives, 31 overhead and underground line configurations were identified for this life-cycle analysis. These configurations, which essentially establish the scope of this assessment, are identified in Tables 1 and 2. While this investigation explored new technology, untried or unproven technology was rejected. Consequently, the scope of the investigation is based on technology that is currently available within the industry. All supporting material, including methodology and cost estimate data, was provided or collected by Acres International Corporation, and is available to the public through the Council.

This investigation also identified expected electric and magnetic fields (EMF) for each line configuration. This variable was used to assess the strength and mitigation

**Table 1. Construction costs[1] and life-cycle costs[2] for various overhead and underground configurations based on a five-mile line. A = Scenario A; B = Scenario B**

| | Construction cost | | Life-cycle cost | | Electric and magnetic fields | | | |
|---|---|---|---|---|---|---|---|---|
| | Load A ($1000) | Load B ($1000) | Load A ($1000) | Load B ($1000) | 500 Amp mG[3] | 1,500 Amp mG[3] | 795 kc mil kV/m[3] | 1,272 kc mil kV/m[3] |
| **Overhead** | | | | | | | | |
| *Single Circuit (I-string insulator except as noted)* | | | | | | | | |
| Wood H-frame | 1,917 | 2,040 | 4,924 | 5,803 | 8.129 | 24.388 | 0.094 | 0.097 |
| Wood H-frame w/ compact spacing | 1,969 | 2,092 | 4,997 | 5,876 | 5.082 | 15.247 | 0.063 | 0.065 |
| Single wood pole w/ delta arrangement | 2,007 | 2,137 | 5,055 | 5,944 | 2.782[4] | 8.345[4] | 0.045[4] | 0.047[4] |
| Steel pole | 2,501 | 2,660 | 5,734 | 6,663 | 5.969[4] | 17.906[4] | 0.041[4] | 0.042[4] |
| Steel pole w/ compact spacing | 2,518 | 2,679 | 5,758 | 6,690 | 5.002[4] | 15.007[4] | 0.037[4] | 0.038[4] |
| Steel pole w/ delta arrangement | 2,441 | 2,595 | 5,649 | 6,572 | 5.051[4] | 15.153[4] | 0.075[4] | 0.078[4] |
| Steel pole w/ compact spacing delta arrangement | 2,429 | 2,561 | 5,632 | 6,524 | 2.782[4] | 8.345[4] | 0.046[4] | 0.048[4] |
| *Double Circuit (I-string insulator except as noted)* | | | | | | | | |
| H-frame | 3,334 | 3,574 | 6,969 | 8,013 | 19.680 | 59.040 | 0.236 | 0.244 |
| H-frame w/ alternative phasing | 3,334 | 3,574 | 6,969 | 8,013 | 10.167 | 30.501 | 0.216 | 0.225 |
| H-frame w/ compact spacing and alternative phasing | 3,450 | 3,690 | 7,133 | 8,176 | 4.514 | 13.541 | 0.117 | 0.123 |
| Steel pole | 3,246 | 3,536 | 6,832 | 7,946 | 11.921 | 35.764 | 0.056 | 0.057 |
| Steel pole w/ alternative phasing | 3,246 | 3,536 | 6,832 | 7,946 | 1.863 | 5.589 | 0.014 | 0.015 |
| Steel pole w/ compact spacing | 3,308 | 3,578 | 6,920 | 8,006 | 9.990 | 29.970 | 0.047 | 0.047 |
| Steel pole w/ compact spacing and alternative phasing using V-string insulators | 3,308 | 3,578 | 6,920 | 8,006 | 0.837 | 2.511 | 0.014 | 0.014 |
| Steel pole w/ compact spacing and alternative phasing using stand-off insulators | 3,519 | 3,770 | 7,217 | 8,276 | 0.743 | 2.228 | 0.013 | 0.014 |

| | Construction cost | | Life-cycle cost | | Magnetic fields | | | |
|---|---|---|---|---|---|---|---|---|
| | Load A ($1000) | Load B ($1000) | Load A ($1000) | Load B ($1000) | 500 Amp mG[5] | 1,500 Amp mG[5] | 100 ft 500 Amp mG[6] | 100 ft 1,500 Amp kV/m[6] |
| **Underground** | | | | | | | | |
| *Single Circuit* | | | | | | | | |
| High-pressure gas-filled | 12,924 | 12,924 | 19,014 | 19,014 | 11.552 | 33.084[7] | 0.062 | 0.179[7] |
| High-pressure fluid-filled | 12,926 | 12,926 | 19,016 | 19,016 | 11.552 | 33.685[8] | 0.062 | 0.182[8] |
| High-pressure fluid-filled w/ closed loop circulation | 13,605 | 13,605 | 19,972 | 19,972 | 11.552 | 33.685[9] | 0.062 | 0.182[9] |
| Self contained fluid-filled | 14,839 | 14,839 | 21,622 | 21,622 | 105.236 | 315.708 | 0.565 | 1.696 |
| Solid dielectric w/ horizontal arrangement | 12,603 | 12,603 | 18,475 | 18,475 | 105.236 | 315.708 | 0.565 | 1.696 |
| Solid dielectric w/ delta arrangement | 12,422 | 12,422 | 18,220 | 18,220 | 49.521 | 148.562 | 0.284 | 0.852 |
| Solid dielectric w/ L-shaped arrangement | 12,422 | 12,422 | 18,220 | 18,220 | 66.572 | 199.716 | 0.399 | 1.198 |
| *Double Circuit* | | | | | | | | |
| High-pressure gas-filled | 24,197 | 24,197 | 35,013 | 35,013 | 22.835 | 56.539[10] | 0.124 | 0.307[10] |
| High-pressure fluid-filled | 23,684 | 23,684 | 34,291 | 34,291 | 22.835 | 57.406[11] | 0.124 | 0.312[11] |
| High-pressure fluid-filled w/ closed loop circulation | 26,477 | 26,477 | 38,223 | 38,223 | 22.835 | 57.406[12] | 0.124 | 0.312[12] |
| Self contained fluid-filled | 27,313 | 27,313 | 39,306 | 39,306 | 170.464 | 501.165[13] | 1.129 | 3.318[13] |

**Table 1 (continued)**

| | Construction cost | | Life-cycle cost | | Magnetic fields | | | |
|---|---|---|---|---|---|---|---|---|
| | Load A ($1000) | Load B ($1000) | Load A ($1000) | Load B ($1000) | 500 Amp mG(5) | 1,500 Amp mG(5) | 100 ft 500 Amp mG(6) | 100 ft 1,500 Amp kV/m(6) |
| Solid dielectric w/ horizontal arrangement | 24,348 | 24,348 | 35,022 | 35,022 | 170.464 | 511.393 | 1.129 | 3.386 |
| Solid dielectric w/ horizontal arrangement & alternative phasing | 24,348 | 24,348 | 35,022 | 35,022 | 92.012 | 276.036 | 0.0564 | 1.693 |
| Solid dielectric w/ vertical arrangement | 24,348 | 24,348 | 35,022 | 35,022 | 161.157 | 483.473 | 1.129 | 3.387 |
| Solid dielectric w/ vertical arrangement and alternative phasing | 24,348 | 24,348 | 35,022 | 35,022 | 80.590 | 241.771 | 0.565 | 1.695 |
| Solid dielectric w/ delta arrangement | 23,717 | 23,717 | 34,134 | 34,134 | 95.086 | 285.257 | 0.565 | 1.695 |

1. Construction costs consist of civil work, materials, administration and engineering, contingency costs, and allowance for funds used during construction. Data provided by Acres International Corporation, under contract to the Connecticut Siting Council, June 1996.
2. Life-cycle costs consist of construction costs, operation and maintenance costs, line losses, and financing costs assessed through present value costing in 1995 dollars for 35 years. Data provided by Acres International Corporation, under contract to the Connecticut Siting Council, June 1996.
3. Calculated at edge of 100-foot wide right-of-way with structure in center of right-of-way except where otherwise noted.
4. Field averaged when asymmetrical line configuration cause unequal field levels on opposite edges of right-of-way.
5. Calculated directly over line at ground level.
6. Calculated at edge of a 100-foot right-of-way at ground level.
7. Winter short-term emergency maximum at 1,432 amperes.
8. Winter short-term emergency maximum at 1,458 amperes.
9. Winter short-term emergency maximum at 1,458 amperes.
10. Winter short-term emergency maximum at 1,238 amperes.
11. Winter short-term emergency maximum at 1,257 amperes.
12. Winter short-term emergency maximum at 1,257 amperes.
13. Winter short-term emergency maximum at 1,470 amperes.

**Table 2. Standard load and operation conditions for transmission lines in the life-cycle assessment**

| | Operating conditions | Load levels | |
|---|---|---|---|
| | | Scenario A 115 kV (Amps) | Scenario B 115 kV (Amps) |
| Summer | Expected average | 350 | 500 |
| | Normal | 1000 | 1250 |
| | Long-term emergency | 1250 | 1500 |
| | Short-term emergency | 1500 | 2000 |
| Winter | Expected average | 350 | 500 |
| | Normal | 1250 | 1500 |
| | Long-term emergency | 1500 | 2000 |
| | Short-term emergency | 1750 | 2500 |

of EMF using reverse phasing, compact spacing, and alternative conductor arrangements for comparison against the overall unit cost of the particular line configuration. Although "there remains 'no persuasive biological evidence that [EMF] can influence any of the accepted stages' of the development of cancer", the Council and others recognized that the controversy over EMF still exists with existing and the development of new transmission lines (Connecticut General Assembly 1995; National Academy of Sciences 1996). As shown in Table 1, the Council and others will be able to assess which transmission line configuration would result in the lowest EMF levels at the lowest per unit cost. The mitigation measures using reverse phasing, compact conductor spacing, and special conductor arrangements are applicable to other voltages, but have only been calculated for the 115 kV configurations presented in this analysis. While the Council has made no endorsement for low-EMF designs, this information may be useful in establishing low-cost alternatives during controversial public siting proceedings for new transmission lines.

This investigation also recognizes that environmental factors are major considerations in the siting, construction, and operation of any type of transmission line — underground or overhead. In the development of a typical transmission line project, the importance of environmental features is reflected in siting and design considerations; in the detailed environmental reviews that regulatory agencies perform as part of permitting processes; and in both construction and operation/ maintenance procedures that are developed and implemented to minimize environmental impacts. While environmental costs are clearly important factors in project planning and decision-making, many of these costs are external and cannot be generically quantified. Such costs can, however, be assessed qualitatively and factored into project-specific analyses.

Reliability was considered as a general factor in system integration and selection of a line configuration, but because the frequency and duration of line failure is speculative, actual costs associated with line repair, replacement of power, and lost revenues have not been quantified and included in the assessment of costs. However, general conclusions regarding relative reliability, causes for failure, repair, and system planning are presented in the section "Findings".

The results of this investigation are both timely and important to the many states considering the restructuring of the electric utility industry in order to accommodate competition from non-utility generators. Although the extent of change in the electric industry is unknown, it is generally accepted that electric transmission systems will continue to operate under a monopoly structure. However, as generation becomes more competitive, the transmission of energy from low-price generators to regions of high demand will become more prevalent, favoring more complex long-distance and regional transmission. Consequently, even with industry restructuring and competitive market-based generation, the development and retrofit of transmission lines will continue to be a controversial public issue under the management of utilities and regulation of state public service commissions. Generic investigations such as this, will help to simplify complex transmission planning, lower costs, increase public participation, and protect both the environment and the public.

## ENVIRONMENTAL CONSIDERATIONS IN LIFE-CYCLE COSTING

Various environmental factors have a bearing on underground vs. overhead transmission line siting, construction, and operation. Although such factors are project-specific, generic evaluations and assessments can be made, and methods for evaluating and comparing such factors, either quantitatively or qualitatively, are available. The analysis of environmental cost factors relevant to transmission line planning was developed based on various agency/utility consultations; the review of published reports, articles, and other documents (refer to references section for a listing); and a field reconnaissance of representative existing 115 kV transmission line rights-of-way maintained by United Illuminating (UI) and Northeast Utilities Service Company (NU) in Connecticut.

### Environmental cost components

Inherent in the life-cycle costs of either an overhead or an underground transmission line are the conventional (direct and indirect monetary) environmental expenditures associated with each project, as well as external costs (or costs to society) as a result of the project. Conventional environmental costs can be budgeted, tracked, and quantified. Currently, however, Connecticut utilities lump most such costs as part of general project expenditures, without breakdown of separate "environmental" cost components. The following are representative project phases for which conventional costs can be tracked and quantified:

- *Project planning and design*, including field surveys to identify environmental resources of concern (e.g., wetlands delineations, cultural resource analyses, stream surveys, endangered/threatened species investigations) and to finalize the alignment of overhead structures or underground facilities so as to minimize environmental impact.
- *Permitting*, including the development of certificate and/or permit applications, environmental reports and maps; permit/certificate application filing fees; support of the permit/certificate applications at agency hearings; and preparation of management plans and other studies as may be required as a condition of certification and/or permit approval.
- *Facility construction*, including the implementation of environmental protection measures and mitigation plans, and environmental monitoring.
- *Facility operation/maintenance*, including right-of-way vegetation control and maintenance activities involving environmental stabilization.

Social costs, also referred to as "externalities", are environmental costs that may result from a project, but are subjective and not easily quantifiable in terms of dollar amounts (i.e., "monetized"). Because they cannot easily be assigned a dollar value, either in the market place or by regulation, externalities typically may not be taken into full account in project decision-making. Examples of externalities include the effect of a view of a transmission structure on aesthetic quality; nuisance effects attributable to noise from overhead transmission lines; and the change in habitat or biodiversity due to the creation of a utility right-of-way.

The following summarizes the four primary phases of a transmission line project and generally identifies both conventional costs and potential environmental externalities.

#### *Project planning and design*

The first phase in the development of any transmission line project is conceptual project design, including the performance of site and environmental evaluations to investigate alternatives (e.g., overhead or underground; configurations; routing; no action) and to refine a preferred alignment. The extent to which special environmental investigations or field surveys (e.g., biological surveys cultural resource investigations, visual analysis, socioeconomic evaluations) are required will be a function of the characteristics of the project area. Consequently, the costs associated with these activities will vary substantially from project to project, regardless of whether the proposed transmission line is overhead or underground.

*Permitting*

Various permits and approvals are required for the construction of a typical transmission line. The types of permits required for a project and the time and cost to apply for and obtain approvals are a function of the scope and impact of the project, and particularly whether any *significant* adverse effects to environmental resources will occur. Costs are incurred by the utilities in preparing, filing, and supporting the permit applications, as well as by the regulatory agencies, who must review and act on the application materials. Most of these types of permitting costs are not specifically allocated as "environmental" expenditures, in a manner that would allow a meaningful cost analysis. Such an accounting is not required by the regulatory agencies and has not traditionally been performed by the utilities. In this regard, the actual costs of environmental permitting are typically "hidden" — that is, although the costs are incurred, they are not recorded so as to allow a specific accounting of environmental expenditures on a project-by-project basis.

For example, UI estimates that its per project permitting costs are in the range of \$100,000 to \$150,000, and notes that this includes the costs for the preparation of an environmental impact statement and other technical reports, permit fees, legal fees relating to environmental permitting, costs of public notices, and miscellaneous expenses (e.g., travel, administrative). However, this cost range was estimated based on only two recent projects, one approximately 0.8 km (0.5 mile) and another 5.1 km (3.2 miles) in length (UI 1995). NU's environmental permitting is performed as part of project engineering, and has not been accounted for separately. NU estimates that engineering is approximately five percent of a large project's total cost, and that for projects requiring a Council certificate, approximately half of the engineering cost is for regulatory work. Recent NU transmission projects requiring a Council certificate have ranged in length from less than 1.6 km (1 mile) to approximately 24 km (15 miles).

*Facility construction*

The construction of a transmission line — either overhead or underground — results in various environmental impacts, which differ in magnitude, duration, and extent, based on the type and location of the project. Conventional costs are incurred to comply with environmental specifications and permit/certificate requirements (e.g., displacement of animals as a result of costs of temporary erosion controls, agency inspections of environmental aspects of construction work, restoration and right-of-way revegetation). *External costs* occur in the form of disturbance to the right-of-way, visual impacts, impacts to biota, nuisance impacts to the public (such as traffic congestion, noise, localized dust emissions), sedimentation into watercourses, etc. Such externalities can only be identified and described qualitatively because many of these impacts are based on public perceptions, which vary individually (e.g., the "value" the public places on a view of a hillside with a visible right-of-way, the "cost" society associates with a change in wildlife habitat, (e.g., removal of mature forest vegetation during clearing to create an open right-of-way; or a temporary decrease in water quality in a wetland crossed by construction equipment). While monetary values cannot be assigned to environmental resource costs, these impacts can be compared for different types of projects, qualitatively.

*Facility operation/maintenance*

As is the case for construction, the operation of transmission lines results in conventional environmental costs that can be (but have not traditionally been) quantified, as well as environmental effects that can only be assessed qualitatively. The primary environmental factors involved in transmission line operation include conventional costs for labor and equipment that are incurred to perform standard right-of-way vegetation maintenance and stabilization (e.g., vegetation control, repair of eroded areas), as well as labor (management or administrative) required to monitor or document compliance with long-term environmental permit conditions (if any), and externalities associated with the maintenance of a maintained right-of-way (e.g., the effects on biological resources, perceived effects on visual resources, and property values).

With respect to conventional costs, the Connecticut utilities have not historically tracked and quantified costs for maintaining and stabilizing rights-of-way. New York electric utility right-of-way maintenance costs have been reported to the New York State Department of Public Service. New York's data indicate that per acre maintenance costs vary substantially, ranging from approximately \$3,300 for trimming to \$72 for foliage herbicide application.

Externality costs associated with the different transmission line scenarios vary substantially depending on the environmental conditions along and in the vicinity of a particular right-of-way, as well as on public perceptions and attitudes. Apart from EMF research (which was not included in the environmental analysis for this life-cycle study), the primary potential adverse effects of transmission lines that have been the subject of research studies to date are: aesthetic impairment (from overhead lines in particular, but also from rights-of-way in general); noise (overhead lines only); habitat fragmentation and/or edge effects; interference with radio reception (localized effects, overhead lines only); and reductions in property values.

No specific studies were identified regarding the environmental effects of the operation/maintenance of an underground transmission line. The environmental externality costs associated with the operation of a transmission line are generally perceived as less for an underground facility than for an overhead facility. However, while underground transmission avoids some of the environmental issues associated with overhead transmission lines (e.g., wire noise, views of structures, potential for certain impacts to wildlife), there remain environmental costs and risks. For example, there is a potential for leaks from oil-filled underground lines, which would have environmental consequences.

Externalities related to rights-of-way, such as perceived effects on property values, and views of a maintained corridor are relevant to both types of transmission lines.

*Externality models (or lack thereof)*

As part of the evaluation of environmental life-cycle costs, available data regarding methods for quantifying and incorporating environmental externalities into life-cycle cost assessments were reviewed. The purpose of this review was to determine the availability of an externality model that could be applied to incorporate environmental externalities into the transmission line siting and review process in Connecticut. However, for the most part, the externality models currently in use for energy planning are narrowly focused on methods for quantifying externalities associated with air emissions from electricity generation. Other types of externalities, such as those associated with resource extraction or energy transportation, typically are not discussed or are identified only on a qualitative basis. In the overall accounting of environmental externalities from power generation, the environmental costs of transmission are considered relatively insignificant (Edison Electric Institute 1994).

A recent environmental externalities study commissioned by the Empire State Electric Energy Research Corporation did generally describe the impacts of electricity transmission, but in the context of new transmission lines that would be necessary to connect new electric generating plants to the power grid. In particular, the study discussed externalities associated with overhead transmission lines, such as damages to land use and terrestrial resources (e.g., aesthetic impairment, noise, radio signal interference, change in open space/biodiversity/habitat), as well as possible adverse effects to human health and to the health of wildlife near transmission lines. However, this analysis was a qualitative review and did not present a model for identifying or ranking transmission line externalities. The study did suggest that the damages associated with loss of open space, terrestrial impacts, and aesthetics could be quantified, on an order-of-magnitude basis, using property value studies (RCG/Hagler Bailey, Inc. 1993).

Another New York State study noted that while the idea of internalizing externalities into overall energy planning and decision-making has conceptual appeal, the actual operational task is made difficult by the almost infinite number of potential externalities (not only environmental, but also those relating to health, safety, and social welfare). The study further noted that externality valuation is a function of society's willingness and ability to pay for perceived benefits or changes in social welfare, which also are very difficult to measure (New York State Department of Public Service et al. 1994).

It would appear that externalities can be easily measured only on a project-specific basis, in situations where an actual value can be attributed to a specific outcome. For example, in order to preserve a forested buffer area between their homes and transmission line, a group of central Connecticut homeowners whose property abutted a transmission corridor within which a new line was to be built paid to relocate the line near their properties to the opposite side of the transmission right-of-way. In this instance, a specific value (the cost of the relocation) can be assigned to the value that the homeowners place on aesthetics.

Other studies and reports (e.g., Buchanan 1990) similarly have noted that it is difficult, if not impossible, to attempt to quantify some environmental externalities, which are in reality environmental risks. Examples are the risk of damage to a National Register of Historic Places site or to a designated threatened or endangered species, to which the allocation of dollar values may be impractical or inappropriate.

Studies (Buchanan 1990) indicate that, in some cases, environmental costs may be integrated into decision-making by evaluating them in terms of society's willingness to pay, based on: cost to control the impact (e.g., costs to adhere to special timing restrictions and crossing techniques to minimize impacts to a sensitive fisheries resource; transmission pole realignment to limit impacts to visual resources); cost to mitigate the impact after the fact (e.g., restoration costs); or damage costs associated with environmental risks (e.g., clean-up costs for a spill of fluid from an underground fluid-filled cable). However, because of the limited historical environmental cost data available for transmission lines, there is little, if any, basis upon which to derive standard estimates for environmental control, damage, or mitigation costs. On the other hand, such costs could be estimated on a project-specific basis to place a value on specific environmental resources of concern.

Finally, some attempts have been made to use matrices and weighted values to compare the external environmental impacts of different types of energy projects. For example, as described by Putta (1990), New York State developed techniques for setting price equivalents for some environmental impacts as part of that state's utility bidding program for power generation. Part of the New York method involved the use of an Environmental

Scoring Form, which lists and weights environmental attributes (e.g., "visual aesthetics" is assigned a weight of 1), along with point scores for different levels of impacts that a project will have on an attribute (e.g., a highly visible project is assigned zero points, whereas one that is not visible from public roads is assigned the highest point ranking of five). Impacts to environmental attributes are scored by multiplying points by the weighted ranking, with a high number indicating a low impact level. Although the New York Environmental Scoring Form was designed for use by utilities in evaluating power projects, it could be adapted for use in decision-making for transmission line projects. However, the use of any matrix weighting scheme necessarily involves value judgments and qualitative comparisons that will always be subject to controversy.

Overall, until (and if) relevant models are developed, environmental externalities for transmission lines are best evaluated qualitatively, and on a project-specific basis.

## FINDINGS

As previously discussed, this analysis assumed that the driving factor for selection of a particular line is in many cases internalized cost. This information is summarized in Table 1 and in Fig. 1. While external costs, aesthetics, site constraints, and the regulatory environment will continue to play an important role in facility selection and construction, the conclusions reached in this analysis are largely based on the fixed costs of construction and operation for each transmission configuration accumulated over a 35-year life-cycle.

The following conclusions can be drawn from this comparison of line configurations.

*Costs*

- Construction costs for typical underground configurations under similar loading are approximately 5–8 times the construction costs of typical overhead configurations (4.9–7.7 times for single-circuit scenario A; 6.7–8.4 times for double-circuit scenario A; 4.6–7.3 times for single-circuit scenario B; 6.3–7.7 times for double-circuit scenario B).
- Life-cycle costs for typical underground configurations under similar loading are approximately 3–6 times the life-cycle costs of typical overhead configurations (3.2–4.4 times for single-circuit scenario A; 4.7–5.8 times for double-circuit scenario A; 2.7–3.7 times for single-circuit scenario B; 4.1–4.9 times for double-circuit scenario B).
- The least expensive single-circuit line is a wood structure H-frame overhead configuration, closely followed by a single wood pole configuration.

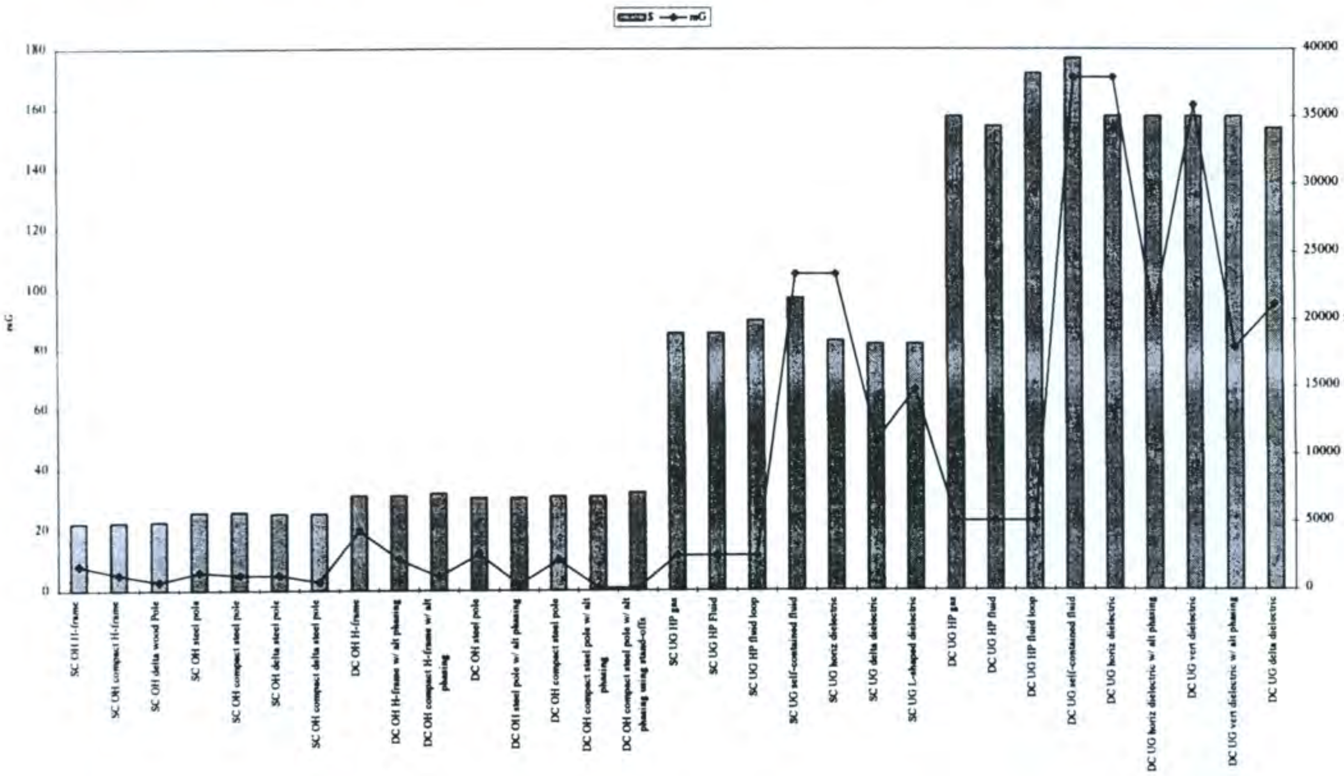



Fig. 1. Comparison of life-cycle costs and magnetic fields for various overhead and underground configurations calculated using standard conditions. SC = single circuit, DC = double circuit, UG = underground, OH = overhead, HP = high-pressure. Magnetic field calculations have assumed exposure from 500 amp of load and access to the edge of a restricted ROW at ground level ( 3–5 ft directly over underground configurations and at ground level at the edge of a 100-ft wide ROW for overhead configurations with the structure in the center of the ROW). See Table 1 for cost and operating conditions.

- The least expensive double-circuit line is a steel pole structure configuration, closely followed by a wood H-frame structure configuration.
- The least expensive underground line is a solid dielectric configuration, closely followed by high-pressure gas-filled and high-pressure fluid-filled configurations.
- Although the solid dielectric configuration is the least expensive underground line, operational history is limited at transmission voltages of 69 kV and above.

*Reliability*
- Overhead configurations are more susceptible to interruption from external sources such as weather, but failure is easier to identify and repair.
- Underground configurations are less susceptible to failure from inclement weather, but identification and repair of the failure is more difficult and will take longer.
- Overhead configurations are more likely to fail due to tree contact and vehicle accident when compared to underground configurations.
- Underground configurations are more likely to fail due to insulation faults, splice faults, termination faults, and dig-ins when compared to overhead configurations.
- Overhead and underground configurations are not always electrically equivalent, and simple one-for-one substitution of underground configurations for overhead configurations is not possible without detailed system engineering to consider current-carrying capability, load sharing, charging currents, fault currents, system restoration, and system losses.

*Electric and magnetic fields*
- The configurations that produce the lowest magnetic fields at the edge of a 100-ft wide right-of-way are underground fluid-filled or gas-filled cables; however, as shown in Fig. 1, public exposure will be lower from many overhead lines if public access is permitted immediately above underground lines, which is typical for underground installations.
- Alternative phasing and conductor cancellation techniques can be effective in reducing magnetic fields for double-circuit lines, but field cancellation may not be uniform across the right-of-way when conductors are horizontally configured and fields between non-canceling phases become additive.
- Electric fields are a function of voltage and shielding, and are non existent at ground level for underground configurations as a result of shielding from the conduit and earth materials.

*Environmental factors*
- Although overhead configurations may have an effect on visual resources, in certain cases impacts on other sensitive environmental receptors such as open meadow inland wetlands may be minimized or avoided with overhead access gaps between line structures.
- Although underground configurations generally have less of an effect on aesthetic resources, trenching may have a greater effect on other environmental receptors unless subsurface installation methods such as boring or directional drilling techniques are used.
- Overhead configurations will generally require wider rights-of-way than underground lines, decreasing their applicability to urban areas where land value is high or conductor clearances are unattainable.

While there will always be a need for detailed cost estimating and engineering to select technology for the construction of a transmission facility at a particular site, this investigation shows that both initial generic construction costs and cumulative life-cycle costs are less for overhead lines than for underground lines. Although still developing, the use of solid dielectric technology, directional drilling, soft trenching, electronically guided boring rigs, underground cable pulling equipment, and combined replacement of aging underground utilities will help lower underground costs at a faster rate than overhead line costs. Furthermore, as these technologies reduce the costs of construction (the critical costs for undergrounding), these technologies and other new technology for cable diagnostics and system refurbishment will increase reliability and make such underground lines easier to maintain (Douglas 1994).

On the horizon is the breakthrough technology of high temperature superconductivity (HTS) power cables. These cables offer potential to increase the capacity of underground conduits for a given size and voltage. Since HTS was first reported by Müller and Bednorz (1987), the temperature for HTS has been increased, applications using thin films, tape, and wire have been demonstrated, and materials are now at or near the point of commercial development (Chu 1995; Kirtley and Tsuei 1996). Wiremaking companies including Sumitomo Electric Industries in Osaka, Japan, Intermagnetics General Corporation in Lantham, New York, and American Superconductor Corporation in Westborough, Massachusetts, all claim to have capacity to manufacture HTS materials (Service 1996). Pirelli Cable Corporation, working with EPRI, American Superconductor, and the Department of Energy seek to develop by 1998, a complete cable prototype to carry 2,000 amperes at 115 kV within an eight-inch steel pipe (Lubkin 1996). This prototype and others are projected to be tested through 1999, and be commercially available by 2000 (Moore 1996).

Although this technology may offer great promise for undergrounding transmission lines in urban areas, HTS could make underground lines an economical option to traditional overhead lines in non-urban areas as well (Moore 1996). HTS, while not yet fully understood, is also expected to be available soon after 2000 to improve efficiency and reduce the size of transformers, power system control and protection equipment, and generators for application in both underground and overhead transmission configurations (Moore 1996). The limiting factor for use of HTS at this time is the low temperature necessary for superconducting, which requires costly liquid nitrogen or helium cryogenic cooling systems (Grant 1995).

HTS has developed rapidly and offers great promise for a number of applications, but the need to use complex and expensive cooling systems may discourage the commercial use of HTS for long-distance transmission lines. Room-temperature super conductivity, while not now considered impossible, has yet to be found (Chu 1995). Consequently, conservative electric utilities may be slow to accept HTS as an alternative to overhead and conventional underground power transmission until such technology is tested and proven to be reliable and cost-effective (Service 1996).

While the data of this investigation does not support underground lines as the least-cost favored option within a 35-year life expectancy, in the future, the cost gap between underground and overhead technologies will become narrower. The narrowing of this cost gap between overhead and underground configurations will be accelerated as:

- the longer a transmission line is in service (beyond the 35-year life expectancy analyzed for this study), as the higher initial construction costs of underground configurations are depreciated over a longer life;
- if certain external costs, including effects on visual resources, property value, and potential health effects associated with overhead transmission lines, are internalized in life-cycle analyses;
- as new technology such as HTS becomes reliable and cost-effective; and
- as the price of electricity increases and line losses, which are lower for underground lines, become more significant due to the increased cost of electricity.

However, with increased competition in the electric transmission industry, electric costs may hold steady or even be reduced, thus continuing to favor initial least-cost overhead configurations. Furthermore, without an allowed rate of return, now enjoyed by utility monopolies and threatened by restructuring, a restructured electric market may favor short-term investments over long-term investments. Thus, overhead configurations may continue to be the preferred configuration as long-distance interstate transmission lines are constructed to facilitate retail and wholesale access.

## ENVIRONMENTAL LIFE-CYCLE COST IMPLICATIONS AND RECOMMENDATIONS

The construction and operation/maintenance of either underground or overhead transmission lines result in both conventional and external environmental costs. Both types of costs should be integrated, either quantitatively or qualitatively, into life-cycle cost assessments and utility/regulatory decision-making. To facilitate the identification, evaluation, and comparison of environmental costs as part of a life-cycle cost assessment, the following are recommended:

1. *Improve tracking of and accounting for conventional costs.* The conventional environmental costs of project planning, permitting, construction, and operation/maintenance should be better tracked in order to allow a comprehensive accounting of the actual expenditures on environmental matters for each project. Hidden costs that could be assigned to specific line segments or projects include labor and materials for project planning; permitting and permitting support; implementation of environmental protection measures during construction; and right-of-way vegetation maintenance.
2. *Integrate environmental externalities into project decision-making.* Environmental externalities should continue to be considered and incorporated into project decision-making for transmission lines. Although externality analyses must continue to rely on qualitative comparisons, rankings, and analyses to evaluate subjective effects, the types of environmental externalities considered in project decision-making can be standardized to facilitate comparisons among project alternatives and types.

## CONCLUSION

As electric load centers continue to grow, and as new generation facilities replace aging baseload facilities owned by utilities, there will continue to be a need to upgrade existing transmission lines and to develop new transmission lines. Decisions regarding the choice of transmission line technology will have profound effects on the environment for several decades, and will be driven by both quantifiable internal costs of construction and maintenance as well as external social concerns regarding the environment and public health. A new paradigm favoring long-distance underground transmission lines is not immediately expected; however, the frequency for selection of underground lines will increase if decisions are based on external life-cycle costs and if underground technology continues to evolve toward higher efficiency and lower cost. Cost drivers may be reinforced through a regulatory environment that would oversee the construction, operation, and maintenance of the transmission system as a natural monopoly even as the electric supply industry becomes more competitive and driven by market forces.

This investigation has been undertaken in cooperation with Acres International Corporation, 140 John James Audubon Parkway, Amherst, NY 14228-1180. Additional information may be found at the Connecticut Siting Council, 10 Franklin Square, New Britain, Connecticut 06051. Supporting material may be acquired from the Connecticut Siting Council at a cost of $50.00 to offset the expense of printing and handling.

## REFERENCES


Buchanan, S.C. 1990. Estimating environmental costs of energy resources. The Electricity Journal, July: 36–41.

Chu, P.C.W. 1995. High-temperature superconductors. Scientific American, Sept.: 162–165.

Connecticut Department of Health, Interagency Task Force. 1995. Task Force activities to evaluate health effects from electric and magnetic fields. Hartford, Connecticut.

Connecticut Siting Council. 1995. Compilation of summary of Connecticut Siting Council review of costs and schedules for transmission line applications. New Britain, Connecticut.

Consumer Energy Council of America Research Foundation. 1993. Incorporating environmental externalities into utility planning: seeking a cost-effective means of assuring environmental quality, Washington, D.C.

Douglas, J. 1994. Cost coming down for underground. EPRI Journal, June: 22–29.

Grant, P.M. 1995. Superconducting superwires. Nature, 375: 107–108.

Kirtley, J.R. and C.C. Tsuei. 1996. Probing high-temperature superconductivity. Scientific American, August: 68–73.

Lubkin, G.B. 1996. Power applications of high-temperature superconductors. Physics Today, March: 48–51.

Moore, T. 1996. Power applications for superconductivity. EPRI Journal, July/August: 6–15.

Müller, K.A. and J.G. Bednorz. 1987. The discovery of a class of high-temperature superconductors. Science, 237: 1133–1139.

National Academy of Sciences, National Research Council. 1996. Possible health effects of exposure to residential electric and magnetic fields.

New York State Energy Office. 1992. Environmental externalities and Energy taxes. New York State Energy Plan, Volume III: Final generic environmental impact statement. Albany, New York.

New York State Energy Office. 1994. Issue #8: Externalities: How should environmental and socioeconomic externalities be considered in state energy decision-making? New York State Energy Plan, Volume II: Issues reports. Albany, New York.

New York State Public Service Commission. 1995. Miscellaneous file data regarding right-of-way maintenance costs: Herbicide use and cost data, various utilities, 1982–1994. Albany, New York.

Northeast Utilities System. 1995. Letter response regarding Connecticut life-cycle costing study. Berlin, Connecticut.

Office of Technology Assessment. 1994. Studies of the environmental costs of electricity. Background paper of the Congress of the United States. Washington, D.C.

Putta, S.N. 1990. Weighing environmental externalities in New York State. The Electricity Journal: 42–47.

RCG/Hagler, Baily, Inc. 1993. New York State environmental externalities cost study report I: Externality screening and recommendations. Prepared for Empire State Electric Energy Research Council. New York, New York.

Service, R.F. 1996. Superconductivity turns 10. Science, 271: 1804–1806.

United Illuminating. 1995. Letter response regarding Connecticut life-cycle costing study. New Haven, Connecticut.


## *BIOGRAPHICAL SKETCHES*


***Joel M. Rinebold***

*Connecticut Siting Council, Ten Franklin Sq., New Britain, CT 06051, USA*


Joel M. Rinebold is the Executive Director of the Connecticut Siting Council, and has worked with the Council since 1985. Prior to serving the Council, Mr. Rinebold worked as District Manager for the Litchfield County Conservation District, and as a land use consultant. In addition, Mr. Rinebold serves as Adjunct Faculty at Central Connecticut State University instructing senior and graduate level environmental planning classes. Mr. Rinebold's academic credentials include a Bachelor of Urban and Regional Planning degree from Central Connecticut State University and a Masters degree specializing in Environmental Planning from the University of Rhode Island.


***Louise F. Mango***

*Phenix Environmental, Inc., 75 Glen Road, Suite 108, Sandy Hook, CT 06482, USA*


Ms. Mango is President of Phenix Environmental, Inc., an environmental consulting business with offices in Connecticut and New York. An environmental consulting professional for more than 20 years, Ms. Mango focuses on environmental and economic impact assessments for energy development and other projects. Ms. Mango's educational credentials include a B.S. in Botany with an Economics double major from Duke University, a M.S. in National Resources from Michigan State University, and a M.B.A. from the State University of New York at Buffalo. She is a Certified Environmental Professional.

# The Alberta Pipeline Environmental Steering Committee: A Model for Cooperative Resolution of Issues

Ian F. H. Scott

With over 244,000 km of pipelines in Alberta, Canada, industry and government traditionally gathered information and conducted research independently to address pipeline environmental issues. The results were often disputed which often led to confrontation between industry and the regulators. In the mid 1980s a series of pipeline environmental issues emerged such as topsoil conservation, three-phase stripping, and reclamation criteria which demanded mutual resolution. Consequently, the Alberta Pipeline Environmental Steering Committee (APESC) was established in 1988. Initially, APESC membership was comprised of industry and provincial government representatives only but has since expanded to include landowner, local government, federal government and pipeline contractor representatives. The paper will discuss the overall mandate of APESC, its objectives, how it operates, examples of current issues being addressed, and how they are managed and prioritized. The paper will demonstrate how the APESC approach has benefited industry, regulators and the public through agreement on issues' identification and mutual resolution.

*Keywords*: Industry, government, public, conflict resolution environmental, pipeline, issue identification and prioritization

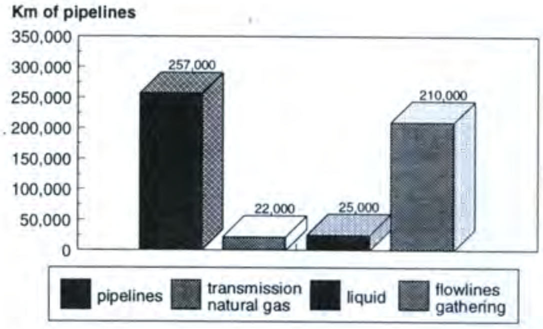
## INTRODUCTION

### Background

In Canada there are approximately 540,000 km of operating oil and gas, pipelines of which about 50% are located in the Province of Alberta. Pipelines operating in Alberta are the responsibility of a number of provincial government agencies. Alberta Energy Utilities Board (EUB) regulates the design, operation and abandonment of flow lines, gathering systems, feeder pipelines and transmission pipelines, while lower-pressure distribution lines (such as cooperative pipelines) are regulated by Alberta Transportation and Utilities. Alberta Environmental Protection (AEP) regulates conservation and reclamation activities for all pipelines; Alberta Farm and Rural Development (AFRD) regulates lines on lands designated as "public lands". Interprovincial and international pipeline systems are regulated by the National Energy Board (NEB). Figure 1 shows the types of pipelines operating in Alberta and regulated by the EUB.

Pipeline operators are represented by two main industry associations: the Canadian Association of Petroleum Producers (CAPP) and the Canadian Energy Pipeline Association (CEPA).

In the late 1970s through the mid 1980s, a series of pipeline environmental issues emerged such as topsoil




CAPP

Fig. 1. Pipelines in Alberta.

conservation, three-phase stripping in problem soils, reclamation criteria and protection of fisheries and fish habitat which demanded mutual resolution by industry and government. In addition, the regulators and the public questioned whether pipeline construction standards and procedures were adequate to address the prevailing environmental issues. To address specific environmental issues, pipeline operators were forced to provide increased information, and develop and implement new construction techniques, some of which were questionable.

### Establishment of the Alberta Pipeline Environmental Steering Committee

Although industry and government conducted independent research and surveys to address the pipeline environmental issues, the results were often disputed. This led to confrontation, frustration, delays and even duplication of effort between the oil and gas industry and the regulators. Consequently, in 1988, the Alberta Pipeline Environmental Steering Committee (APESC) was established to address pipeline environmental issues in a concerted, cooperative way. Initially, APESC membership only comprised industry and provincial government representatives but it has been expanded to include landowner, local government, federal government and pipeline contractor representatives.

The remainder of this paper provides an overview of the overall mandate of APESC, its objectives, how it operates, examples of current issues being addressed, and how these issues are managed and prioritized.

## THE ALBERTA PIPELINE ENVIRONMENT STEERING COMMITTEE

### APESC mandate

APESC provides a forum that allows pipeline environmental concerns to be identified early in the process before they become issues of major confrontation between respective stakeholders. The mandate of APESC is:

> "To assist industry, government and other stakeholders in the collective pursuit of ensuring environmental protection as it relates to the planning, construction, operation, abandonment and reclamation of pipelines, while recognizing sound economic objectives."

APESC essentially has four objectives: to ensure environmental protection while considering the economics during all phases of a pipeline from design to abandonment; to act as a vehicle for government to receive input from industry and other stakeholders during policy formation; to identify, prioritize and make recommendations for workable solutions on pipeline environmental issues; and to implement recommendations by organizations represented on APESC.

APESC provides a forum for government to receive input from industry and other interested groups during the development of government policy, legislation, regulations and guidelines. This forum provides a mechanism for any party to identify pipeline-related environmental issues, to prioritize the issues and to develop and recommend workable solutions to industry and government. Each stakeholder assists in the collective implementation of the recommendations through their respective organization.

### APESC's committee structure

Initially, APESC comprised members from industry and government. Through a regular review of the membership, representatives from other interested parties have been identified and the membership has expanded. Currently, APESC's membership consists of:

*Industry*
- CAPP (three representatives)
- CEPA (three representatives)
- Pipeline Contractors Industry (one representative)
- Utility Pipeline Industry (two representatives)

*Government*
- AFRD (two representatives)
  Farmers Advocate of Alberta
  Public Land Management Branch
- AEP (four representatives)
  Land Reclamation Division
  Land and Forest Service
  Fish and Wildlife Division
- EUB (one representative)
- NEB (one representative)
- Alberta Association of Municipal Districts and Counties (AAMDC) (one representative)
- Surface Rights Federation of Alberta (one representative)

### APESC structure

APESC is co-chaired by industry and government. Co-chairs are appointed or volunteer their services for a period of not less than one year. Meetings are held at least quarterly with meeting locations rotating between Calgary and Edmonton, these being industry and government centres, respectively.

Depending on the location of the meeting, the respective industry or government chair is responsible for developing an agenda, its circulation, organization and chair of the meeting. The agenda is developed through informal discussions between the co-chairs and their respective constituents.

APESC annually appoints one of its members as secretary. The secretary is responsible for drafting and circulating minutes of meeting. Minutes from each meeting are approved at subsequent meetings.

In December, an annual meeting is held to review APESC's membership, the chair positions, the secretary, progress of APESC activities, and identify future direction. The co-chairs develop an annual report which is circulated to the appropriate senior industry and government officials.

## APESC process

*Issue identification*
Members may raise issues at any time. Each issue is discussed and consensus is required before APESC will place the issue on the Issues Priority List. Issues are reassessed and priorities re-evaluated at the annual meeting. The Issues Priority List can be reviewed at every meeting and modified accordingly.

An issue is listed on the Issues Priority List under one of three main areas:
- Policy Development
- Standard Development
- Information/Process Requirement.

Each issue is prioritized as high, medium or low, assigned a project manager(s) to oversee resolution of the issue, and assigned a time-frame in which to resolve the issue. Table 1 provides an example of the current issues being addressed by APESC.

*Priority setting and terms of reference*
At each annual meeting, current and new issues are reviewed and prioritized. A member of APESC is assigned to oversee and report regularly on progress of resolution of an issue. An issue may be addressed by APESC itself or through the establishment of task forces. The responsible member develops, for APESC approval, Terms of Reference for the Task Force.

*Establishment of task forces*
When APESC determines it is appropriate to establish a task force, APESC members are requested to identify representatives to sit on the task force. The responsible APESC member identified as the task force chair contacts potential representatives and convenes a meeting.

The task force operates under the Terms of Reference established by APESC. Task force progress reports are made at each APESC meeting. If the task force requires clarification about its Terms of Reference or wishes to amend them it must report back to APESC to obtain approval before the task force's mandate can be changed. The task force is responsible for developing recommendations within a specified time-frame and bringing them forward to APESC for review and consensus.

*Funding*
For planning purposes, APESC prepares a three-year forecast of the funds needed to address the issues identified. This forecast enables industry and government to identify annual funding requirements so funding can be included in their respective budgets.

Once a task force has been established, the task force may, if it deems funds are required to resolve the issue, provide a written request to APESC outlining funding needs, how the funds would be used and when the funds are required. APESC reviews the request using the three-year forecast as a financial guide. If support for funding is accepted, APESC members seek the appropriate amount from their respective organizations. Wherever possible, joint funding between government and industry is preferred.

*Implementation of recommendations*
Following the tabling of recommendations, APESC reviews them, seeks consensus and determines an appropriate course of action. APESC members are expected to discuss the recommendations within their respective organizations and seek ratification. Final decisions of APESC are usually communicated through written notification such as regulatory "Informational Letters, Interim Directives, Discussion Papers or Guidelines". Each APESC member is expected to assist in the communication and implementation of the recommendations. For example, CAPP regularly publishes notices in its monthly newsletter ReCAPP to alert members of such new information.

*APESC successes*
APESC has successfully resolved a number of issues in recent years. These include development of jointly sponsored industry/government workshops on pipeline

**Table 1. Current Alberta Pipeline Environmental Steering Committee (APESC) issues**

| Issue | Description | Assigned to | Due date | Comments |
|---|---|---|---|---|
| P1 | Abandonment | Etherington, Sharp | Q 3 1996 | Develop discussion paper |
| P2 | Link with APIGEC | APESC | Ongoing | APIGEC, CPWCC, CAPP, CEPA, PASC |
| P3 | Provincial/Federal regulatory issues | Brocke, Sharp, Etherington | Ongoing | Regulators provide update to APESC |
| P4 | Third-party impacts on reclamation | Brocke, Etherington | Q3 1996 | Position statement for approval |
| S1 | Reclamation criteria | P/L Task Group | Q2 1997 | Reclamation criteria for post-construction |
| S2 | P/L Guide pursuant to AEPEA | Chymko | Q1 1997 | Issue new guide for pipelines |
| S3 | Hydrostatic Testing Management G/L and Code | Scott | Q4 1996 | Revision to existing guidelines and new government code |
| I1 | Review problem Soils Handling Guideline | Soils Task Force | Q3 1996 | Salinity field study, review of three lift guidelines |

reclamation criteria, pipeline water crossings and protection of fish habitat, cooperative work to address environmental issues related to pipeline abandonment, development of a pipeline guide to assist industry in understanding the legislative requirements of the Alberta's Environmental Protection and Enhancement Act, identification of areas under that legislation that require clarification (e.g., requirements for hydrostatic testing) or eliminating requirements which were considered unnecessary (e.g., elimination of requirement for reclamation security deposit prior to pipeline construction). A brief review of APESC's approach to dealing with pipeline reclamation criteria demonstrates how the APESC model can benefit all stakeholders.

Historically, few pipeline reclamation certificates have been issued in Alberta. Consequently, there has been little pressure on government or industry to have clearly defined reclamation criteria. However, a number of separate actions in the early nineties changed this.

In 1990, the Canadian Institute of Chartered Accountants, the ruling body for chartered accountants, changed the accounting rules requiring companies to identify reclamation costs as a liability in their financial reports. This action precipitated the need to define reclamation (and associated costs) which resulted in a joint industry/government workshop in May 1994, the purpose of which was to identify the factors that should be considered to determine the success of reclamation. Also, pipeline abandonments began increasing as Alberta's infrastructure aged and upstream wells (and associated flowlines) were abandoned. In addition, AEP released the "*Reclamation Criteria for Wellsites and Associated Facilities*" which provided detailed reclamation criteria for the upstream oil and gas industry.

In March 1994, an industry/government task force (established under the auspices of APESC) developed and released the "*Guide for Pipelines Pursuant to the* (Alberta) *Environmental Protection and Enhancement Act and Regulations*". This document consists of three parts:
- Approvals
- Environmental Protection Guidelines
- Reclamation Certification.

The third section noted that specific pipeline reclamation criteria were not yet available and only wellsite criteria existed.

Industry commissioned a study to suggest pipeline reclamation criteria and tabled this with APESC. Government did not accept the criteria proposed and, as a result, APESC struck a task force to develop criteria. Representation on the task force includes industry, government and the farming community. After a number of meetings, the task force reported back to APESC that it was having difficulty in proceeding past the initial stages because industry and government were entrenched in their positions about what the reclamation criteria should be. APESC reviewed their concerns and the task force membership and after considerable debate, changed the task force's representatives by replacing the "scientists" with "issues management people". As well, more specific directions were given to the task force. Some of the specific concerns raised included:
- Would the criteria apply to post-construction and or/post-abandonment? APESC directed the task force to consider the former first then address the latter.
- Would the criteria evaluate reclamation success on the basis of productivity or capability? Since the Act uses capability as the basis for determining reclamation success, APESC agreed this would be used but the issue on how to implement capability in a meaningful cost effective manner was left to the task force to address.
- Could issue managers identify the reclamation criteria parameters and then hand them over to a group of "scientists" to identify the thresholds? APESC decided this approach was reasonable and hoped the issue managers would not become embroiled in the details that resulted in the initial stalemate.

Since fall 1995, the task force has been meeting on a regular basis to develop pipeline reclamation criteria with a goal to have recommendations for interim criteria for APESC's approval in spring 1997. If approved, these criteria will then be implemented on a trial basis in the summer of 1997 to evaluate their appropriateness.

*Elements for success*

All stakeholders agree the APESC process has been effective resolving conflict in an efficient manner. Furthermore, stakeholders recognize that if APESC is to remain successful and productive, members must remain vigilant of the conditions needed to continue to build on the successes. These include:

(1) Members must have a clear mandate from their respective affiliation from the highest level of their organization.

(2) Full participation from all members is essential for success. Companies representing industry must recognize the time, effort, costs and commitment associated with full participation on such committees.

(3) Member organizations should be committed to funding projects jointly agreed upon. Where possible, joint funding of projects should be encouraged to ensure joint management of a project. However, if for example, a member feels strongly about a particular issue and study is required to resolve it, funding should be provided by that member.

(4) There must be a clear understanding of the ratification process (including definition of consensus) so that any actions or recommendations agreed upon by the committee can be implemented. Similarly, development and understanding of a conflict resolution process is essential.

(5) Members should be open-minded and remain flexible in their positions to ensure win-win resolution of issues.

**SUMMARY**

This paper has demonstrated how the APESC approach has benefited Alberta's pipeline industry, regulators and the public, and others outside of the province, to achieve mutual resolution on complex and difficult pipeline related environmental issues. Through a multi-stakeholder process which ensures there is agreement on the issues to be addressed, classification and prioritization of the issues in terms of Policy Development, Standards Development or Information/Process Requirements, and time frame to resolve the issues has resulted in less confrontation between industry, government and other stakeholders. The APESC process has resulted in better day-to-day working relationships between the stakeholders having an interest in pipeline related environmental issues. In addition the process encourages stakeholders to address concerns early on an industry wide basis rather than at a specific project level and thereby minimizes the potential for frustration, confrontation and project approval delays.

**ACKNOWLEDGEMENTS**

The author would like to acknowledge Messrs. Larry K. Brocke Director, Land Reclamation, Alberta Environmental Protection, and Fred Kuipers, Supervisor, Environmental Affairs, Pembina Corporation, Calgary who developed the original paper for the International Pipeline Conference held June 1996, in Calgary, Alberta which Mr. Scott presented on their behalf at that conference.

---

*BIOGRAPHICAL SKETCH*

***Ian F.H. Scott***

*Canadian Association of Petroleum Producers, 2100, 350-7 Avenue, S.W., Calgary, Alberta, Canada T2P 3N9*

Ian Scott is currently Manager of Pipelines, Environment and Operations with the Canadian Association of Petroleum Producers, an industry association representing the Canadian upstream oil and gas industry. He has over 23 years of pipeline experience. He has a Masters in Environmental Engineering and a Bachelor of Science in Mathematics.

# Resource Protection Through Maryland Licensing Requirements

**Sandra Shaw Patty, John L. Magistro, and Sandra Collins**

In Maryland, electric utilities must obtain a Certificate of Public Convenience and Necessity (CPCN) from the Maryland Public Service Commission before constructing new transmission lines greater than 69,000 volts. Maryland's Power Plant Research Program (PPRP) within the Department of Natural Resources coordinates the interagency reviews of CPCN applications and development of conditions issued with the CPCN that minimize effects to the State's resources. PPRP recently evaluated the effectiveness of the CPCN conditions issued in Maryland for minimizing environmental impacts associated with the construction, maintenance and operation of transmission lines. Conditions were grouped into four main categories: (1) right-of-way clearing and transmission line construction; (2) erosion and sediment control; (3) right-of-way maintenance; and (4) protection of waterways and wetlands. Many general conditions are part of the utility's standard operating practices. Specific conditions provided additional protection to sensitive resource areas on a case-by-case basis. Results of the site inspections indicate that the conditions have effectively minimized environmental impacts associated with the construction, operation and maintenance of transmission line rights-of-way in Maryland. The utilities have also incorporated a variety of voluntary measures to restore and enhance environmental conditions within and adjacent to the transmission corridors.

*Keywords*: Maryland, transmission line, right-of-way, construction, maintenance, environmental protection, environmental stewardship, wildlife habitat

## INTRODUCTION

Electric utilities in Maryland must obtain a Certificate of Public Convenience and Necessity (CPCN) from the Maryland Public Service Commission (PSC) before constructing a new transmission line. When granting a CPCN for a new transmission line, the PSC includes conditions recommended by the Maryland Departments of Natural Resources, Agriculture, Environment, Transportation, and Business and Economic Development, the Office of Planning and the Energy Administration. The Department of Natural Resources, Power Plant Research Program (PPRP) coordinates the State's review of transmission line projects and the development of measures recommended to minimize adverse effects to the State's natural and socioeconomic resources. The CPCN conditions recommended by these State agencies have evolved over the past twenty years to reflect the increased understanding of potential environmental impacts resulting from construction and operation of transmission lines, changes in environmental legislation, and changes in public concern over the construction and operation of transmission lines.

PPRP recently examined the CPCN conditions issued for transmission line projects in Maryland. This study was undertaken as part of PPRP's efforts to promote a natural resources stewardship within Maryland's electric utility industry consistent with the statewide goals and objectives established by DNR. The objective of this review was to evaluate the effectiveness of the conditions in minimizing potential environmental impacts associated with the construction, maintenance and operation of transmission lines. This paper presents the results of this study.

## METHODS

We prepared a summary matrix of all CPCN conditions issued for transmission line cases certified since

**Table 1. Transmission lines selected for evaluation of CPCN conditions**

| PSC case no. | Project name | Electric utility | Size (kV) | Length (km) | Proposed order date | Geographic setting |
|---|---|---|---|---|---|---|
| 8430 | Easton-Steele | Delmarva Power and Light Company | 138 | 38.6 | 2-3-92 | Coastal Plain (rural) |
| 8282 | Cecil-Colora | Delmarva Power and Light Company | 230 | 24.9 | 5-9-91 | Coastal Plain (rural/suburban) |
| 8255 | Finksburg-Westminster | Baltimore Gas and Electric Company | 115 | 15.8 | 1-9-91 | Piedmont (rural/suburban) |
| 8158 | Messick Road-Cumberland-Marlow | Allegheny Power Systems | 138 | 2.1 | 5-9-89 | Allegheny Plateau (rural/suburban) |
| 7977 | Northwest-White Rock | Baltimore Gas and Electric Company | 115 | 18.5 | 12-24-86 | Piedmont (rural/suburban) |
| 7833 | Black Oak-Fort Ashby | Allegheny Power Systems | 138 | 1.4 | 9-25-84 | Allegheny Plateau (rural) |
| 7498 | Montgomery-Damascus-Mt. Airy | Allegheny Power Systems | 230 | 23.2 | 8-5-82 | Allegheny Plateau (rural/suburban) |
| 7461 | Waugh Chapel-Marriott Hill | Baltimore Gas and Electric Company | 115 | 19.6 | 6-30-81 | Coastal Plain (rural/suburban) |
| 7004 | Brighton-High Ridge | Potomac Electric and Power Company | 500 | 16.9 | 4-6-79 | Piedmont (rural/suburban) |

1979. For this paper, we selected those conditions that could be evaluated during a site visit, such as right-of-way construction and design (access roads, pole location, pole height, span length, and pole placement techniques); right-of-way maintenance (selective vegetation management, establishment and maintenance of stream, wetland, and roadside buffers); erosion and sediment control measures (leaving roots and stumps during right-of-way clearing and the establishment of native ground cover); and protection of waterways and wetlands (expanded buffer zones, avoidance and minimization measures). Using the summary matrix we identified conditions common to all projects and those that were unique to a specific project or environmental setting.

Once we had selected the conditions to be evaluated, we identified transmission lines for the site visits. Individual transmission line projects were selected to represent (1) all applicable CPCN conditions; (2) the various environmental settings found in Maryland (e.g., Coastal Plain, Piedmont and Appalachian Plateau provinces; rural, suburban and urban land uses); and (3) a range of old and new projects so that construction and maintenance impacts could be assessed over time. The four electric utilities included in the study were Allegheny Power Systems (APS), Baltimore Gas and Electric Company (BGE), Delmarva Power and Light Company (Delmarva) and Potomac Electric Power Company (PEPCO). Table 1 provides a summary of the nine transmission lines selected for field investigations. Figure 1 presents the general location of each transmission line.

The purpose of the transmission line site visits was to assess the efficacy of the conditions in minimizing environmental impacts, and record general observations on the transmission lines. We determined the effectiveness of each condition based on direct field observations, e.g., evidence of erosion and sediment deposition, vegetation establishment along the right-of-way, presence of vegetated buffers, and location of poles and/or access roads outside of sensitive areas. Additional information obtained from the utility companies during the site visits included (1) problems or difficulties experienced in implementing the conditions, (2) observations made during the implementation of the conditions, (3) suggestions on alternatives that would have resulted in the same level of environmental protection but at a lower cost to the utility, and (4) voluntary measures implemented by the utilities during line construction and maintenance.

Following completion of the field investigations, we summarized the observations and findings to determine the overall success of the CPCN conditions in minimizing environmental impacts. The following section presents this summary and the experiences of the utility companies in complying with these conditions.

## RESULTS AND DISCUSSION

Those CPCN conditions that could be evaluated during a site visit were grouped into four main categories: (1) right-of-way clearing and construction; (2) erosion

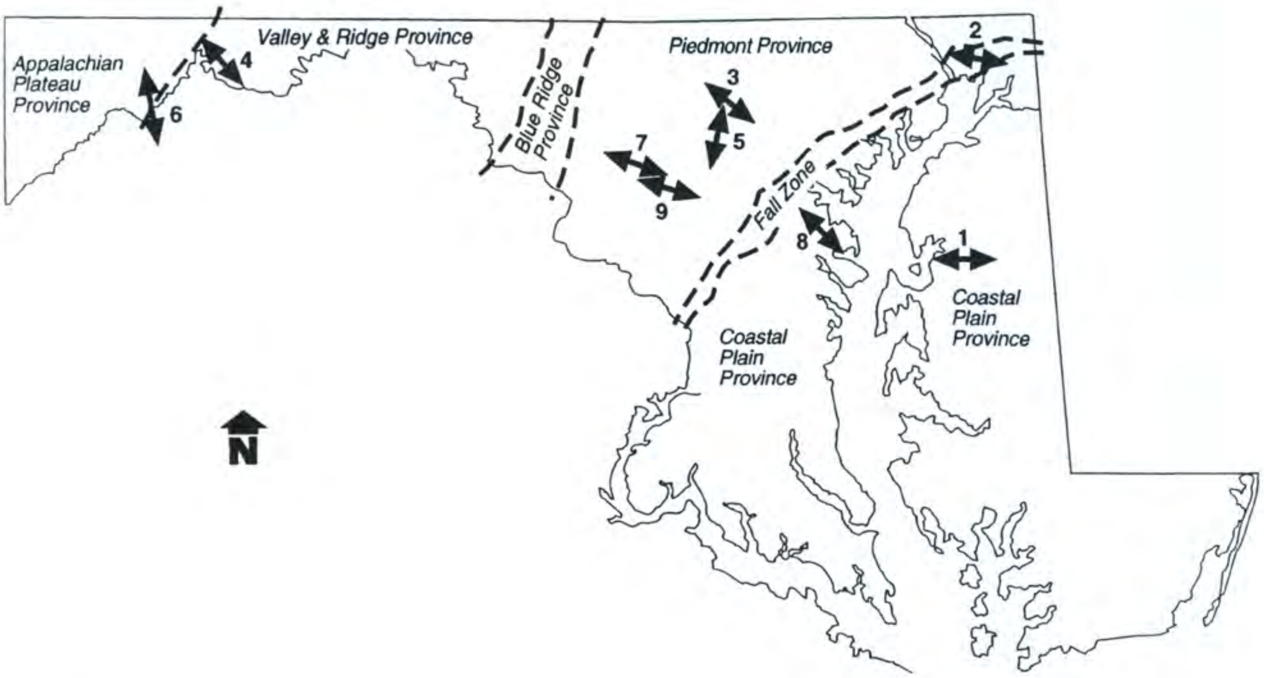



Fig. 1. Location of transmission lines selected for evaluation of CPCN conditions in Maryland. For key, see Table 2.

**Table 2. Key to Fig. 1**

| Key | Utility company | PSC case no. | Line length (km) | Line size (kv) |
|---|---|---|---|---|
| 1 | Delmarva Power | 8430 | 38.6 | 138 |
| 2 | Delmarva Power | 8282 | 24.9 | 230 |
| 3 | Baltimore Gas & Electric | 8255 | 15.8 | 115 |
| 4 | Allegheny Power | 8158 | 2.1 | 138 |
| 5 | Baltimore Gas & Electric | 7977 | 18.5 | 115 |
| 6 | Allegheny Power | 7833 | 1.4 | 138 |
| 7 | Allegheny Power | 7498 | 23.2 | 230 |
| 8 | Baltimore Gas & Electric | 7461 | 19.6 | 115 |
| 9 | Potomac Electric Power | 7004 | 16.9 | 500 |

and sediment control; (3) right-of-way maintenance; and (4) protection of waterways and wetlands. Observations on the effectiveness of the general conditions, as well as examples of site-specific conditions observed during the field inspections are provided below.

### Right-of-way clearing and transmission line construction

General right-of-way clearing and transmission line construction conditions common to all projects included leaving roots and stumps in place during initial clearing; collocating with existing road, railway and transmission line rights-of-way where possible to minimize vegetation removal; increasing pole heights at stream crossings to minimize removal of riparian vegetation; and avoiding placing poles in waterways and wetlands. The site inspections indicate that the utility companies have complied with the CPCN requirements and that these general conditions are effective in minimizing impacts to the environment.

Conditions specific to each project were also found to be effective. For example, specific CPCN conditions issued for construction of Delmarva's Easton to Steele line (PSC Case #8430) limit the right-of-way width within Tuckahoe State Park. The easement that the State and Delmarva negotiated for Delmarva's existing 69 kV line did not permit an increase in the right-of-way width. Therefore, in order to use the existing right-of-way through the park, Delmarva chose to replace the existing 69 kV H-frame poles with two side-by-side, single poles, one for the existing 69 kV line and one for the new 138 kV line. No evidence of additional right-of-way disturbance was observed during the site visit. This condition was successful in minimizing impacts within the State Park because no additional right-of-way clearing was necessary.

In general, the utilities have not experienced difficulties in implementing the CPCN conditions. However, one exception was noted along PEPCO's Brighton to High Ridge line (PSC Case Number 7004). A specific condition required PEPCO to avoid access road crossings through the Little Patuxent River. In order to comply with this condition and still have access to poles adjacent to the Little Patuxent River, PEPCO's only option was to construct a permanent access road on steeply sloping terrain in an area with relatively unstable soils. During the site visit, PEPCO indicated that they have had periodic erosion and washout problems along portions of the access road. The utility has implemented a number of road stabilization and drainage improvement projects in this area to minimize future erosion problems. Although this condition successfully avoided crossing the Little Patuxent River the problems associated with the road instability increased the potential for periodic sediment loading into the Little Patuxent River and subsequent repair/maintenance costs for the utility.

### Erosion and sediment control

General erosion and sediment control conditions, such as re-seeding exposed soils following construction and leaving roots and stumps in place during initial line clearing, are standard practices among Maryland electric utility companies included in this study. No erosion or sediment problems were observed during the site inspections. Re-planting and re-seeding efforts have effectively minimized line clearing impacts. The site inspections indicate that these general conditions are effective in minimizing erosion and sedimentation problems.

Specific erosion and sediment control conditions were issued for the portion of BGE's Waugh Chapel to Marriott Hill line (PSC Case Number 7461) within the North River drainage basin, which provides important habitat for migratory fish. The conditions limited construction in the North River to 1 June through 1 October (i.e., non-migrating and non-spawning period), and specified that vegetation had to be retained or replaced at stream crossing points to minimize erosion and sedimentation damage to fish eggs and larvae. No erosion or sediment problems were observed within this area during the site inspection, indicating that these conditions have effectively minimized impacts to stream habitat. In addition to the CPCN requirements, BGE has taken voluntary steps to further minimize erosion potential. BGE maintains raised, horizontal berms along the steep portions of its access roads to slow down the movement of surface runoff and minimize potential erosion and siltation problems. BGE also maintains an expanded vegetative buffer in steeply sloped areas within the drainage basin by taking advantage of the pronounced topographic relief to increase pole span length and conductor height. This provides further stabilization of soils and reduces potential run-off problems.

### Right-of-way maintenance

Observations made during the site inspections indicate that the general right of way and maintenance conditions have proven effective in minimizing adverse impacts to natural habitat. These conditions require the use of selective clearing and maintenance along each of the rights-of-way, but do not specify what methods should be used. This allows the utilities to adapt their right-of-way management practices to the various physical and biological parameters present within each geographic area. All of the utilities that participated in the study practice some form of selective vegetation maintenance (Fig. 2). Although their management approach differs, the goals and objectives are similar—to use selective vegetation management to ensure line


Fig. 2. Examples of selective vegetation maintenance practices: (a) Delmarva maintains a stable shrub community through selective hand clearing and selective chemical spraying; (b) BGE uses infrequent, specified mowing to maintain a stable meadow community; (c) PEPCO selectively removes fast growing vegetation where necessary to maintain a stable shrub community; (d) APS uses selective spraying with limited cutting to maintain a stable low growing shrub community.

access and line integrity while improving right-of-way habitat, specifically, plant species and plant structural diversity. A discussion of each of the utilities' vegetation management strategies is presented in the following paragraphs.

Delmarva's Maryland service area is in the Lower Coastal Plain Province of Maryland's Eastern Shore. This area is predominantly rural, with sandy soils and relatively flat to gently rolling topography. Delmarva uses selective hand clearing and selective chemical spraying for all transmission line maintenance to promote the development of a stable shrub-scrub plant community. The Lower Coastal Plain's fertile soils, relatively mild temperatures and long growing season promote rapid re-vegetation of disturbed areas and development of the preferred plant community. The Lower Coastal Plain also contains vast areas of tidal and non-tidal emergent wetlands which may cause line access and maintenance problems. Delmarva uses aerial spraying in these remote areas to control the growth of undesirable emergent wetland species such as the common reed (*Phragmites* sp.) and encourage growth of native species.

BGE's Maryland service area covers portions of the Upper Coastal Plain, Fall Zone and Piedmont provinces. Topography varies from relatively flat to gently rolling in the Coastal Plain, to moderately and steeply sloping in the Fall Zone and Piedmont provinces. The Baltimore-Washington metropolitan corridor is within this service area and much of the land has been converted from agricultural use to urban and suburban use. In densely populated areas, BGE uses adaptive management. In some circumstances, BGE mows the entire right-of-way on a regular basis to blend in with the surrounding residential landscapes. However, along some of the less developed portions of its rights-of-way observed during this study, BGE practices infrequent, specified mowing. The goal of the specified mowing is to promote a stable meadow community dominated by native herbaceous species. This goal is accomplished by adjusting mowing schedules to late-summer and fall to prevent trees and shrubs from taking over the meadowlands while avoiding both the reproductive period for target plant species and wildlife nesting periods. BGE also mows selected strips to allow the growth of low growing and slow growing shrub species, such as flowering dogwood and American holly, within portions of the right-of-way to provide structural diversity and foraging habitat for wildlife.

PEPCO's Maryland transmission lines are located in the densely populated urban and suburban areas within the Upper Coastal Plain, Fall Zone and Piedmont provinces. PEPCO also regularly mows the entire right-of-way in densely populated areas. Along the less developed portions of its lines, PEPCO typically mows only the access road and, when necessary, selectively removes fast growing vegetation to maintain a more "natural" vegetative state along the right-of-way.

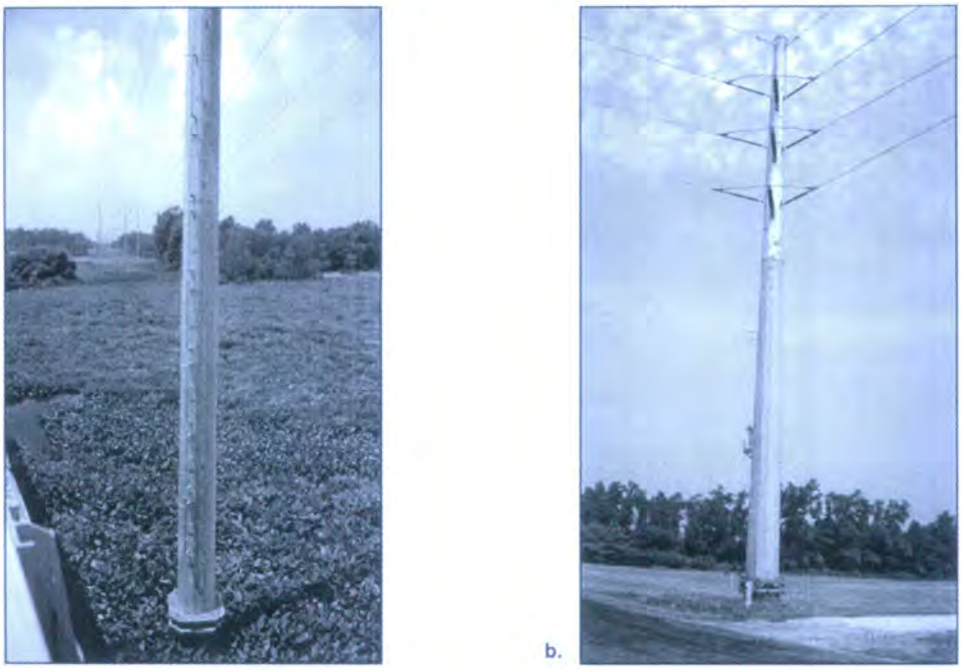
The APS service area in Maryland includes portions of the Piedmont, Blue Ridge, Valley and Ridge and Appalachian Plateau provinces. These areas are moderately to steeply sloping, and are either forested or used for agriculture. APS uses selective maintenance, primarily spraying with limited cutting, for their transmission lines. The current vegetation management strategy is to promote establishment of a stable community of low-growing shrub species within the right-of-way. In order to minimize potential erosion problems along its rights-of-way, APS re-seeds all disturbed areas with a five-seed mixture of fast-growing species: orchard grass, timothy, perennial rye, annual rye, and spring or winter wheat (depending on the time of year) which stabilize the soils until the low-growing shrub community becomes established.

One right-of-way maintenance condition, the topping of trees, though effective, may require unsafe utility operations. A CPCN condition associated with PEPCO's Brighton to High Ridge line (PSC Case Number 7004) specifies selective removal and topping of trees in environmentally sensitive areas along the Patuxent River. During our site inspection, PEPCO indicated that although they are currently adhering to the CPCN conditions, the current tree topping strategy poses a hazard to work crews due to tree rot and subsequent tree instability. As an alternative, PEPCO suggests using a tree height threshold where PEPCO would selectively remove trees greater than 12.2 m (40 ft) in height. PEPCO suggests coordinating this selective clearing practice with the appropriate resource agencies to inventory existing tree species composition and structure, and develop a management practice that maintains a desirable species composition and distribution.

Another right-of-way vegetation management condition related to selective herbicide use, may unduly restrict the implementation options of the utility. A condition for APS' Montgomery to Damascus to Mt. Airy line (PSC Case Number 7498) restricts the use of herbicides within the right-of-way to selective basal spraying. APS typically uses selective, low volume foliar spraying to control fast-growing woody species along its rights-of-way. APS indicates that foliar spraying is a more cost-effective and ecologically viable approach for controlling nuisance species within its service area. Conditions that prescribe specific vegetation management techniques should be reevaluated in future transmission line cases because they do not allow the utility the flexibility to use measures that work best for them and still protect the environment, nor do they allow for future improvements in management techniques.

### Protection of waterways and wetlands

General CPCN conditions designed to protect waterways and wetlands place limitations on the type of work and clearing allowed in and near waterways, limit vehicle traffic, restrict clearing and stockpiling of



a. b.

Fig. 3. Delmarva's use of the vibrating can foundation for transmission line pole foundation construction in: (a) unstable soils with high water tables such as the emergent wetland area adjacent to the Choptank River; and (b) in sandy soils where minimal foundation footprint disturbance was required by the property owner.

materials in wetlands, and specify that placing poles within these sensitive areas should be avoided. The general conditions evaluated during the site visits have proven effective.

Specific CPCN requirements for Delmarva's Easton to Steele line in the Lower Coastal Plain (PSC Case Number 8430) limit the extent of disturbance to wetlands. In order to minimize construction impacts to wetlands, Delmarva installed foundations using a "vibrating can" method for transmission line pole construction in portions of the right-of-way. This method involves driving a three to six foot diameter, hollow, steel can, 15 to 40 feet into the ground using a vibratory hammer suspended from a crane. It reduces ground disturbance and can often be used in soil conditions unsuitable for typical pole placements, such as unstable sandy soils or soils with high water tables. One particularly sensitive area along the line was an emergent tidal wetland next to the Choptank River. Due to the distance between upland areas, lack of topographic relief and road and bridge obstructions, Delmarva was not able to span the wetland area. Delmarva used the vibrating can method from the highway bridge to place the pole foundation at a depth of 12.2 m (40 ft) without impacting the surrounding wetland areas (Fig. 3a). Delmarva was also able to use this approach in sandy upland soils where a minimal foundation footprint was required (Fig. 3b).

### Voluntary environmental enhancement measures

In addition to complying with the CPCN conditions, the utilities have implemented a number of voluntary measures to restore and enhance environmental conditions within their transmission line rights-of-way. One example involved the restoration of fish habitat in Little Elk Creek. Philadelphia Electric Company, whose subsidiary Conowingo Power was the original builder and owner of Delmarva's Cecil to Colora transmission line (PSC Case Number 8282), and the State of Maryland, removed an abandoned railroad bridge from Little Elk Creek during construction of the Cecil to Colora transmission line (Fig. 4). Flotsam had collected at the bridge pilings and obstructed the natural stream flow. The diverted stream was cutting into the soft stream bank and causing localized erosion and subsequent siltation problems downstream of the obstruction. To mitigate this problem, the bridge pilings were cut at the substrate surface to reduce flow obstruction and to restore the natural stream channel dynamics. The floodplain area around the former bridge location is now well vegetated and more "natural" stream flow patterns have been restored. An oxbow channel and a vegetated sand bar area have developed within the former stream channel, providing additional structural diversity for aquatic and terrestrial species.

Delmarva has implemented a voluntary, system-wide management strategy to promote increase bird breeding opportunities along its rights-of-way. Delmarva has installed approximately 450 bird boxes for bluebird, owl and kestrel along many of its lines and substations. Company volunteers install and monitor the nest boxes, which are obtained from a non-profit work/learning program for developmentally disabled adults. Delmarva also monitors its transmission and distribution lines to identify existing or potential osprey nesting sites. Delmarva has successfully relocated

Fig. 4. (a) An abandoned railroad bridge blocked Little Elk Creek causing local flooding and restricting fish passage; (b) Conowingo Power (now part of Delmarva) and the State of Maryland removed the bridge during construction of the Cecil to Colora line; (c) the creek now flows freely and riparian vegetation has been restored.

35 osprey nests on their transmission and distribution lines to ensure line reliability (minimize potential impacts for line outages) as well as the safety of the birds.

PEPCO voluntarily reduced the right-of-way width from 200 to 150 feet along the Brighton to High Ridge line (PSC Case Number 7004) by switching to an alternate pole configuration. This reduction in right-of-way width provided several economic and environmental benefits: reduction in costs to purchase or lease the right-of-way lands; reduction in line maintenance costs; reduction in vegetation disturbance associated with initial line clearing; and reduction in the extent of tree trimming and tree topping. PEPCO further notes that the alternate pole configuration has reduced electromagnetic field (EMF) generation.

APS has implemented an education/public outreach program within residential areas adjacent to the Montgomery to Damascus to Mt. Airy (PSC Case Number 7498) right-of-way. Many homeowners consider the adjacent right-of-way to be an extension of their backyard and routinely plant trees within these open areas. In response to this potential maintenance problem, APS distributes brochures to homeowners identifying trees that are aesthetically pleasing and compatible with the utility's right-of-way vegetation management strategies. APS has also implemented a tree planting program to replace undesirable, fast-growing trees with low growing shrub species at no cost to the adjacent homeowners.

BGE is currently working with the US Fish and Wildlife Service (FWS) on a butterfly habitat management study along a portion of the Waugh Chapel to Marriott Hill right-of-way (PSC Case Number 7461). The FWS is conducting species surveys, and identifying egg laying and feeding habitats within the right-of-way. BGE is coordinating their specified mowing activities with the FWS and adjusting mowing schedules to maintain and/or expand suitable meadow habitat, and to protect butterflies, within this portion of the right-of-way. BGE has also developed a Meadowland Habitat Management Program in cooperation with DNR to create meadowlands and shrub communities on some of its right-of-way through native grass and wildflower plantings, cyclical mowing, and selective herbicide application.

## SUMMARY AND CONCLUSIONS

The majority of the CPCN conditions are effective in minimizing environmental impacts associated with the construction, operation and maintenance of transmission line rights-of-way in Maryland. Many of the CPCN conditions were common to all transmission line cases and are part of the utilities' standard operating practices. For example, specific sediment and erosion control measures are typically included in the erosion and sediment control plans required by the county prior to granting a construction and/or grading permit. Many of the conditions specified for right-of-way clearing and design, such as location of access points and pole structure placement to avoid sensitive areas, are incorporated into the project during the siting phase in response to regulatory concerns. Selective vegetation management is the standard right-of-way maintenance practice for the Maryland utilities who participated in the survey. Although the management approach is slightly different among each of the utilities, they all strive to ensure line access and line integrity while improving overall wildlife habitat.

A few of the CPCN conditions were found to be too inflexible for future transmission line cases. For example, restricting the use of herbicides to specific types or manufacturers does not allow for future improvements in management techniques. A restriction on access roads to protect water quality in the Little Patuxent River required the utility to construct a permanent access road on steeply sloping terrain in an area with relatively unstable soils adjacent to the river. The utility has implemented a number of road stabilization and drainage improvement projects to correct periodic erosion problems in this area. In this instance the State did not adequately assess the potential alternative effects associated with trying to avoid wetland impacts. The condition specifying selective tree removal and topping to maintain the existing vegetative community at stream crossings may have been too restrictive in the measures to be used. Although the utilities have successfully implemented selective removal and tree topping in sensitive areas, tree topping can pose a safety hazard to work crews due to tree instability. Using a tree height threshold, e.g., selectively removing trees greater than 12.2 m (40 ft) in height, in these areas may provide the same level of species diversity and habitat value, while at the same time, minimizing hazards to work crews.

Each of the utilities surveyed have also incorporated a variety of voluntary measures into construction and management of their rights-of-way. These measures are designed to restore and enhance environmental conditions within and adjacent to the right-of-way corridors. These voluntary measures, in combination with the CPCN conditions, have proven successful in PPRP's efforts to promote a natural resources stewardship ethic while allowing Maryland's electric utilities to expand their transmission systems.

## ACKNOWLEDGEMENTS

Funding for this study was provided by the Maryland Department of Natural Resources – Power Plant Research Program. We wish to thank the following utility companies and individuals for their cooperation and support: Allegheny Power Systems (Chip Brown, Mark Korn, Trevor Lanham, Keith Martin, Claudine Orloski and Sharon Ross); Baltimore Gas and Electric (Tom Benassi, Dan Davis, Chad Devine, Ted Ringger, John Tiemann and Len Wrabel); Delmarva Power and Light Company (Frank Cascino, Richard Johnstone, William Hamilton, Robert McElhaney and Joseph Riding) and Potomac Electric Power Company (David Bailey, A.A. Taousakis, David Paduda and George Carlisle). Special thanks to Phil Mallon of Environmental Resources Management, Inc. for his assistance during the site inspections.

## *BIOGRAPHICAL SKETCHES*

***Sandra Shaw Patty***

*Maryland Department of Natural Resources, Power Plant Research Program, Tawes State Office Building, B-3, Annapolis, MD 21401-2397, USA*

Ms. Patty is an Energy Resources Manager for the Maryland Department of Natural Resources, Power Plant Research Program (PPRP) in Annapolis, Maryland, where she serves as the transmission program manager, responsible for conducting studies assessing all aspects of the electric transmission network in Maryland. She received her BS in Biology from California State College in 1973, and a Masters of Energy Resources from the University of Pittsburgh in 1983.

***John L. Magistro***

*Agriculture Conservation Innovation Center (ACIC), 1400 Wilson Boulevard, Suite 1100, Rosslyn, VA 22209, USA*

Mr. Magistro is a Senior Ecologist with Environmental Resources Management, Inc. with extensive technical and regulatory experience in wetland, wildlife, and contaminant issues throughout the United States, with particular emphasis in the energy production and rail transportation industries. Mr. Magistro received his BA and MS in Biology from Slippery Rock University in Pennsylvania.

***Sandra Collins***

*Environmental Resources Management, Inc., 2666 Riva Road, Suite 200, Annapolis, MD 21401, USA*

Ms. Collins is a Senior Environmental Scientist with Environmental Resources Management, Inc., with more than ten years experience managing and performing environmental impact assessments, and biological field investigations for power plant and transmission line siting projects. Ms. Collins received her BS in Environmental Science and Resource Management in 1981 and an MS in Biology from Lehigh University in 1984.

# Part V
# Cultural

# Methods of Overhead Transmission Line Construction and Prevention of Disturbance to the Archaeological Record: An Example from the Pennsylvania Piedmont

Daniel G. Roberts

A multi-phased archaeological survey in southeastern Pennsylvania in association with PECO Energy's (formerly Philadelphia Electric Company) design of new overhead transmission lines provided an opportunity to observe the relationships between various transmission line construction practices and associated disturbance to archaeological sites. In this paper, various types of overhead transmission line support structures constructed by PECO Energy and their generalized construction methods are presented, followed by a discussion of the potential disturbances to archaeological sites found in Pennsylvania's Piedmont soils attributable to those structures and methods. Such disturbances are evaluated in terms of soil disturbance and archaeological data loss potentially resulting from the various construction methods. It is intended that this evaluation will be of some benefit to members of the electric utility industry involved in future efforts with regard to archaeological resources planning.

*Keywords*: Direct and secondary effects; artifact exposure, breakage, and displacement; lattice structure; tubular steel pole; clearing and selective thinning; access roads; coring and blasting; uprooting of stumps; counterpoise system; ballast rock

## INTRODUCTION

Rapidly expanding energy requirements spurred by explosive population growth and concomitant industrial, commercial, and residential development have recently created the need for considerably expanded electrical power service in many parts of the country. As a result, many new or expanded generating facilities are currently being planned, are now under construction, or are already in operation. Many of these facilities require new or upgraded transmission lines in order to provide the expanded services necessitated by burgeoning regional development. One such facility requiring upgraded lines in the 1980s was the Limerick Nuclear Generating Station, owned and operated by PECO Energy (PECO) and located on the left bank of the Schuylkill River in Montgomery County, Pennsylvania. Some segments of the required Limerick transmission lines were slated for new rights-of-way, but the majority were designed to replace existing transmission lines as part of the overall upgrading of electrical power service.

As part of the environmental permitting process of the Nuclear Regulatory Commission (NRC), approximately 62 miles of transmission line right-of-way in the vicinity of the Lower Schuylkill River were surveyed for archaeological sites (Phase I), numerous support structure and temporary access road locations were subjected to archaeological evaluation (Phase II), and archaeological data recoveries (Phase III) were completed at three significant sites that could not be avoided by construction. Although none of the archaeological results of that work are presented in this paper, such results can be found in six reports (Zatz 1984; Zatz, Joiré, and Hoffman 1984a, 1984b; Zatz, Joiré, Hoffman, and Rast 1985; Zatz, Robertson, and Struthers 1989; Kingsley, Robertson, and Roberts 1990) submitted to PECO and on file at the Pennsylvania State Historic Preservation Office in Harrisburg. One of these reports (Kingsley, Robertson, and Roberts 1990) summarizes in a synthetic fashion the current body of knowledge pertaining to the prehistoric archaeological record of the Lower Schuylkill Valley. Instead, the focus of this paper is on the opportunity provided during the course of this study to observe the relationships between various transmission line construction practices, potential disturbance to the archaeological record in Pennsylvania's Piedmont, and the prevention of such disturbance.

## PREVIOUS RELATED STUDIES

Numerous studies have been conducted on the effects that various logging techniques impart to soil structure (Garrison and Rummell 1951; Steinbrenner and Gessel 1955; Dyrness 1965; Fredriksen 1970; Froehlich 1976), water resources (Brown 1975; Patric 1976), and vegetation (Ruth 1967; Klock 1975). All of these studies were undertaken in the context of forest-related logging enterprises, with particular emphasis on soil disturbance and resultant loss. None explicitly address effects to archaeological sites and, indeed, this type of study is conspicuously rare in the archaeological literature. Notable exceptions, however, include DeBloois, Green, and Wylie's (1975) investigation of the effects of pinyon-juniper chaining methods on archaeological sites in the desert southwest, and Gallagher's (1978) study that measured the effects of scarification techniques (ground preparation for replanting) on archaeological sites in the Sawtooth National Forest of south-central Idaho.

Of particular significance to the present study, however, is the 1965 work of C. T. Dyrness, who studied and classified the nature and extent of soil disturbance as a result of tractor and high lead logging in the Oregon Cascades. Moreover, the work of Bryant, Gehr, and Flenniken (1982) is also highly relevant to the present study. Bryant, Gehr, and Flenniken's study also evaluated the effects of the same two logging techniques studied by Dyrness (that is, tractor over bare ground and high lead cabling) but instead of focusing solely on soil disturbance, Bryant and his associates addressed the nature and extent of archaeological data loss resulting from those techniques.

Bryant, Gehr, and Flenniken (1982) identified four environmental factors that typically affect the nature and extent of surface disturbance. These factors include degree of slope, soil moisture content, soil type, and type of understory vegetation. In general, Bryant and his associates found that the first two factors are the most critical, in that the greater the slope and soil moisture content, the greater will be the effects to the soil surface resulting from disturbance activity. In this regard, Dyrness (1965) notes that disturbance is considerably less during dry conditions when soil moisture content is low. Bryant, Gehr, and Flenniken (1982) also identify two principal types of disturbance, including immediate direct effects (such as plowing and soil displacement), and delayed or secondary effects (such as loss of soil permeability, resulting in increased erosion). Bryant, Gehr, and Flenniken (1982) further point out that direct effects by such agents as tractors or plows normally result in the occurrence of one or more of the following three classes of data loss from an archaeological site:

Class 1. Artifact breakage and/or modification;

Class 2. Artifact displacement, resulting in alteration of contextual associations with soil strata and cultural features; and,

Class 3. Exposure of artifacts on the surface, resulting in eventual artifact loss.

Of these classes of archaeological data loss, Bryant, Gehr, and Flenniken (1982) consider Class 1 (artifact breakage) to result in the least amount of data loss, Class 3 (artifact exposure) to result in an intermediate loss of data, and Class 2 (artifact displacement) to result in the greatest data loss.

Although not explicitly concerned with archaeological sites, Dyrness (1965) established four classes of soil disturbance that are nevertheless quite useful when evaluated in conjunction with Bryant, Gehr, and Flenniken's (1982) three classes of archaeological site disturbances. Dyrness' (1965) soil disturbance classes include the following:

Class 1. Undisturbed: litter still in place with no evidence of disturbance;

Class 2. Slightly Disturbed: litter partially removed and undisturbed mineral soil exposed, with litter and mineral soil intermixed at approximately 50 percent of each;

Class 3. Deeply Disturbed: surface soil removed and subsoil exposed, soil surface seldom covered by litter,

Class 4. Compacted: obvious soil compaction caused by heavy equipment.

With regard to the relative effects to archaeological sites near the ground surface, Bryant, Gehr, and Flenniken (1982) point out that Dyrness' Class 2 and 3 soil profiles (i.e., slightly and deeply disturbed) are the most detrimental, with both normally resulting in severe direct effect. Although Dyrness' Class 4 disturbance (i.e., compaction) may result in the direct effect of artifact breakage, its most prevalent type of effect is secondary. That is, compaction normally produces much lower soil permeability, thus resulting in the secondary effect of erosion and run-off and, perhaps, ultimate artifact displacement and/or loss.

In the sections that follow, techniques utilized in constructing overhead transmission lines are evaluated in relation to the classes of soil disturbance set forth by Dyrness (1965) and the classes of archaeological data loss defined by Bryant, Gehr, and Flenniken (1982). It is intended that this analysis will be of some benefit to the utility industry, and archaeologists serving as consultants to the utility industry, in future planning efforts with regard to archaeological resources.

## TYPES OF OVERHEAD TRANSMISSION LINE SUPPORT STRUCTURES

There are three types of transmission line support structures commonly constructed today by PECO. These include the lattice structure, the railroad overbuild structure, and the tubular steel pole. The predecessor of these three support structures was the single or H-frame wooden pole. These poles, although still visible in many rural areas and still commonly constructed in parts of the western United States (Nick Chevancee and John Bridges, Western Area Power Administration, personal communication, 1997) are rarely newly constructed by PECO, primarily because they do not provide sufficient support for PECO's high voltage needs (Peter Cava, PECO Energy, personal communication 1985).

Lattice-type support structures occur in various specific shapes and sizes but, in general, all are supported by four inverted stub-angle pyramids of galvanized steel, each in turn supported by a concrete foundation (PECO 5-7080-D 1986). The lattice structures are normally constructed of aluminum, not galvanized steel, and can be pre-assembled in sections either off- or on-site. Although varying in height, depending on specific transmission requirements and localized topographic conditions, most lattice structures are between 19.8 and 30.5 m (65 and 100 ft) tall.

The railroad overbuild structure is normally employed in situations where a support structure is required along a currently occupied railroad right-of-way or if joint use of an extant railroad structure is desirable (PECO 1968). This structure normally has only two support columns of single-beam galvanized steel construction. Like the lattice-type structure, the railroad overbuild structure is also supported by concrete footings. Again, the height of a typical railroad overbuild structure varies according to specific conditions, but structures as tall as 33.5 m (110 ft) are not uncommon.

The final type of support structure is the tubular steel pole. Tubular steel poles are manufactured in sections and, although they can be pre-assembled elsewhere (PECO 5-7080-E 1986), they are normally assembled on-site. Unlike the lattice or railroad overbuild structures, the tubular steel pole normally requires only a single concrete footing. The tubular steel pole can be considered the modern-day analog to the old single wooden pole, although it is not necessarily the cheapest support structure to build. Occasionally, tubular steel poles are placed in multiple-pole configurations, such as in a three pole deadend structure. Tubular steel poles are generally taller than lattice-type structures, frequently attaining heights of 35.1 m (115 ft) or more.

The spacing of support structures across the landscape, no matter which type is erected, is largely dependent on local topographic and demographic conditions, as well as conductor size. However, the general rule of thumb for PECO is to erect as few structures as possible and still have a serviceable and safe line. This goal is in accordance with PECO's (1968) written policy which states that a primary goal is "to provide right-of-way which is pleasing in appearance and as unobtrusive as possible, without jeopardizing the high reliability inherent in the Electric Company's transmission system." In order to accomplish this goal, the location and spacing of structures may vary greatly by consideration of several factors, including the avoidance of structure locations on hilltops, the utilization of railroad or limited access highway rights-of-way, the erection of structures at the edge of a wooded area rather than in it, and the utilization of shorter spans and lower structures if structure height is a distinct visual detriment (PECO 1968). Importantly, effects to archaeological sites can frequently be avoided within the rather wide latitude afforded by support structure location requirements (Weir 1986; Gilbert/Commonwealth 1988). In short, the spacing of transmission line structures is accomplished by careful planning and design tailored to each topographic, demographic, visual, and/or cultural situation, and not by a rigid incremented spacing pattern.

## METHODS AND TECHNIQUES OF CONSTRUCTION

In general, four aspects of transmission line construction can potentially affect the integrity of archaeological sites. These four include (a) clearing and selective thinning of right-of-way, (b) construction of access roads, (c) coring and blasting (when necessary) for concrete footings, and (d) installation of a counterpoise system. Each is discussed below.

### Clearing and selective thinning of right-of-way

In keeping with PECO's (1968) policy of creating right-of-way which is "...pleasing in appearance and as unobtrusive as possible...", vegetational clearing is normally kept to a minimum, as long as the safety and reliability of the transmission facility is not compromised. Thus, wherever possible, a policy of "selective thinning" is followed. This practice entails the selective removal of shrubs and brush comprising the understory, as well as the thinning of "danger trees". Danger trees are defined as

> Any tree or shrub which, in whole or in part, exists or grows within the 'danger zone' with respect to power line safety. Where most of the tree falls within the danger zone, the tree shall be removed (PECO 1968).

This practice normally results in less than total clearing of vegetation. Although the width of the "danger zone" is not specified in PECO's policy, it has a direct relationship to the height and voltage of the transmission line *vis à vis* the height and proximity of the vegetation. Total clearing of vegetation (i.e. clear-cutting), however, is sometimes required along portions of a right-of-way. Situations which normally require this technique include locations where additional area is needed for the pulling of cable, areas where woods and/or "danger trees" are extremely dense, and areas of small but dense understory growth which present potential fire hazards (PECO 1968).

### Construction of access roads

Temporary roads for the provision of access for construction teams are frequently necessary. Such temporary roads are limited by specification to 4.6 m (15 ft) in width (PECO S-7080-B 1983) and, once constructed, are the only access roads used by construction vehicles. Since much of the equipment necessary for erecting towers is quite heavy, as are the structures themselves (especially if assembled off-site), the roads can be somewhat substantial. Accordingly, the 4.6-m (15-ft) wide right-of-way normally is graded to at least one foot below surface, with the spoil piled on either side of the cut, and the cut infilled with ballast rock. After the structures are built and the access road is no longer needed, the ballast rock frequently is removed and the spoil replaced in the roadbed (Zatz, Joiré, and Hoffman 1984a). In areas requiring direct access to the public road system, the access road is normally paved with asphalt for a minimum distance of 6.1 m (20 ft) from the public road (PECO 1968).

Temporary roads occasionally are required to provide access across streams or creeks although, in most cases, alternative access from the opposite side is possible. In cases where streams must be crossed, galvanized steel corrugated pipe is laid down, covered with an earth and stone fill, and each stream bank is graded as necessary into the culvert in order to provide sufficient passage (PECO 5-7080-B 1983). When such roads spanning creeks have served their purpose for support structure construction, the corrugated pipe is left in place to aid in drainage and in case stream passage is needed in the future.

It should be noted that, once again, it is PECO's stated policy to minimize the impact of construction of such access roads. This is done by locating the access roads so as to interfere with property use as little as possible, and by aligning the access roads at angles which avoid vistas up the transmission line (PECO 1968). Every effort is also made to use pre-existing access roads, farm lanes, construction staging areas, or other similar extant facility to gain access to support structure locations. However, such facilities frequently consist only of packed earth, and lack sufficient subbase to allow the transport of heavy equipment and supplies, thereby necessitating the building of temporary roads to the specifications noted above.

### Coring and blasting for concrete footings

Before overhead transmission structures of any type can be erected, coring must be undertaken to accommodate substantial concrete footings. In the case of lattice support structures, four such footings are required, one for each stub-angle support. Furthermore, two separate coring operations are required for each structure location, the first to drill test holes to determine the presence and/or depth of bedrock, and the second to dig the holes for each footing. Most holes for footings in the southeastern Pennsylvania Piedmont are excavated to bedrock, but occasionally, design depth is reached before encountering bedrock (PECO S-7080-C 1986).

According to specifications, all excavated holes are to have vertical sides (PECO S-7080-C 1986). Although the diameter of the hole varies depending on the type of structure slated for the location (PECO S-7080-C 1986), most of the holes excavated for the new Limerick transmission lines were between 6 and 10 feet in diameter (Zatz 1984; Zatz, Joiré, and Hoffman 1984a; 1984b; Zatz, Joiré, and Hoffman, and Rast 1985; Zatz, Robertson, and Struthers 1989). The holes are normally excavated using an auger drill, and the holes are then lined with reinforcing bar and/or corrugated or smooth steel casings, and filled with concrete to specification (PECO S-7080-C 1986).

Several ancillary activities associated with coring for concrete footings occasionally take place as required. First, small diversion ditches or swales can be built in order to prevent rain or surface water from accumulating in the excavated hole (PECO S-7080-C 1986). Second, excavated backfill, normally consisting of "clear, dry, well-graded fill material," can be placed "in a graded embankment... in the immediate vicinity of the structures" (PECO S-7080-C 1986), and must be tamped in 61-cm (2-ft) increments. In cases where grading is undertaken, final grade is required to conform as closely as possible to that of the surrounding area (PECO S-7080-C 1986). Finally, although infrequently required, blasting may be necessary if rock impenetrable with an auger drill is encountered prior to achieving design depth. Such blasting is self-contained, however, to deeper subsurface bedrock deposits (Peter Cava, PECO Energy, personal communication 1986).

### Installation of counterpoise system

A counterpoise installation entails connecting copper wire to the support structure for purposes of grounding. This copper wire is installed at a minimum of 61 cm (24 in) below grade, and connected to a wire protruding from the concrete foundation. Only those support structures "where footing resistance measurements by the Power Company indicate such installations are required" (PECO S-7080-G 1983) are subject to counterpoise installation. Although the length and pattern of a counterpoise system can vary, in general, such wires are "laid in a longitudinal direction along the line" (PECO S-7080-G 1983). The use of a small trencher or narrow blade plow is recommended for excavating to the required 61 cm (24 in), and each trench must immediately be backfilled and tamped (PECO S-7080-G 1983).

## POTENTIAL DISTURBANCE TO THE ARCHAEOLOGICAL RECORD

Although the goals of the archaeological survey associated with the upgrade of the Limerick transmission lines primarily focused on the location/identification, evaluation, and data recovery (where necessary) of archaeological sites in advance of planned future construction, the survey also made it possible provisionally to evaluate the types and severity of ongoing and prior disturbance to the archaeological record as a result of support structure construction. The following section briefly evaluates each of the previously noted methods of construction *vis à vis* their effects to archaeological sites, where such effects could be detected. The evaluation is presented in relation to Dyrness' (1965) four classes of soil disturbance and Bryant, Gehr, and Flenniken's (1982) three classes of archaeological data loss.

### Clearing and selective thinning of right-of-way

Clearing and selective thinning of right-of-way, as previously noted, is normally kept to a minimum and undertaken only in areas of heavy vegetational growth where it is not possible to route a transmission line elsewhere. All structure locations, however, must also be cleared of any vegetational impediments to their construction, but these areas are normally only as large as necessary to undertake construction in the footprint of the structure (PECO S-7080-B 1983). Clearing operations generally require several types of activities including, as necessary, selective removal of trees and undergrowth, selective pruning or trimming of same, and stump removal. The services of a private tree clearing contractor is usually required who will utilize, as appropriate, equipment such as a truck and brush chipper, and perhaps a rotary cutter. Much of the actual work, however, is undertaken by hand, using chain saws and other tree-cutting implements.

It is important to note that areas of actual disturbance to the archaeological record as a result of generalized right-of-way clearing are frequently difficult to detect. Areas of total clearing, of course, can result in rather severe surface, and perhaps subsurface, disturbance, since the clearing crew is required by specification to "clear and *grade* (emphasis added) a 4.6-m (15-ft) wide trail to be used as an equipment roadway at locations... designated on specific job specification and/or drawing" (PECO S-7080-B 1983). The nature and extent of such grading, of course, is left up to the contractor as required by site-specific conditions, but grading of any kind doubtless has the potential to compromise the integrity of archaeological sites, particularly those near or at existing grade, such as many of the sites located in the shallow upland soils of the Pennsylvania Piedmont. Such clearing techniques normally would result in Dyrness' (1965) Class 3 (deeply disturbed) and Class 4 (compacted) soil profiles, and Bryant, Gehr, and Flenniken's (1982) Class 1, Class 2, and Class 3 archaeological data loss (i.e., artifact breakage, displacement, and exposure).

A specific clearing technique which can be detrimental to localized areas of archaeological sites is the occasional practice of uprooting trees, rather than the normal practice of cutting them off flush with the ground surface. Either method is acceptable, according to specification (PECO S-7080-B 1983), but uprooting requires permission of the electric company, and in areas with an existing slope of 25 percent or less all stumps *must* be cut off flush with the surrounding grade, with uprooting not permitted. If uprooting does occur, the contractor is bound by specification (PECO S-7080-B 1983) and policy (PECO 1968) to grade and seed with appropriate ground cover. Such grading and seeding of course, has the potential of increasing the area of more localized archaeological disturbance precipitated by the uprooting operation, and would probably result in localized occurrences of Dyrness' (1965) Class 3 (deeply disturbed) and Class 4 (compacted) soil profiles, as well as Bryant, Gehr, and Flenniken's (1982) Class 1, 2, and 3 (i.e., artifact breakage, displacement, and exposure) archaeological data loss.

Physical evidence of disturbance resulting from clearing activities previously conducted in order to construct the extant Limerick transmission lines was scarce. The only clearing activity directly observed during the archaeological investigation was the selective thinning and pruning operation necessary to prevent the encroachment of vegetation into the "danger zone" previously noted and to allow for the access of equipment for new support structure construction. However, as noted above, any grading activity has some potential to compromise the integrity of archaeological sites, particularly those occurring at shallow depths. For example, it was observed by Ranere and Hansell (1983) during a transmission line survey in the Pinelands of southern New Jersey that "the entire transect had been disturbed by the initial clearing of the right-of-way". However, the Limerick right-of-way was characterized in most places either by cultivated fields or low ground cover which had regenerated after the initial clearing in the early to mid-twentieth century. Moreover, most of the cleared rights-of-way not presently under cultivation had been subject to plowing at some point in the past. Consequently, although numerous disturbed soil profiles were encountered during subsurface testing, many such profiles were attributed to historical plowing activities, rather than to right-of-way clearing activities undertaken by PECO.

### Construction of temporary access roads

The construction of temporary access roads has the potential of contributing considerable disturbance to the archaeological record. As noted previously, the construction of such roads is avoided if at all possible. When necessary, however, a cut approximately one foot in depth, 4.6 m (15 ft) in width, and as long as necessary to traverse between two points, is made. Clearly, in a previously undisturbed area, such a road can seriously disturb or destroy the upper levels of archaeological sites extant in the right-of-way. In areas previously subjected to plowing, however, of which there were many in the project area, the potential for adverse effect is somewhat less since plow disturbance normally slightly exceeds one foot in depth. Areas such as previously existing farm lanes may be subject to less disturbance as well. Wherever access roads must cross streams, however, the associated laying of corrugated pipe and the grading of both stream banks has the potential to compromise archaeological sites which may exist in the vicinity.

The subsequent removal of ballast rock from the temporary access road cut, together with associated grading necessary to restore the area as nearly as possible to its former condition, can also further disturb an existing archaeological site, particularly if the restoration process requires relatively deep grading. However, it should be recalled that the intent in *all* aspects of temporary access road construction and removal is to do only the minimum necessary to transport heavy equipment over an otherwise inaccessible area. In many cases, in fact, temporary access roads become permanent additions to the landscape at the request of an affected landowner, so that removal and restoration is not undertaken.

No evidence for disturbance from the prior construction of access roads was observed during the transmission line survey. However, one access road was newly constructed at the location of a significant archaeological site, with appropriate mitigative measures taken (see later comments). In general, Dyrness' (1965) Class 2 (slightly disturbed) and Class 3 (deeply disturbed) soil profiles can be expected in areas where temporary access roads have been built, as can Bryant, Gehr, and Flenniken's (1982) Class 1, Class 2, and Class 3 archaeological data loss (i.e., artifact breakage, displacement, and exposure).

### Coring and blasting for concrete footings

The coring operations necessary to anchor overhead transmission line support structures, whether of the lattice or tubular steel pole variety, appear in many instances to have a very localized potential effect on the integrity of archaeological sites. As noted previously, all excavated holes are normally 1.8–3.1 m (6–10 ft) in diameter, have vertical walls, and are dug with an auger drill. As a result, there is little or no horizontal disturbance during the coring operation, such as occurs in grading or cutting. However, localized grading of the coring spoil, which is sometimes necessary to restore the immediately surrounding area to its original condition, especially if sloppily done, can cause more disturbance to the archaeological record than the actual coring operation. The occasional need for diversion ditches or swales to keep water out of the excavated hole can also have implications for the integrity of the archaeological record, but these are only infrequently necessary. Indeed, none were observed during the Limerick project. Similarly, the occasional need for blasting at bedrock levels appears to have little bearing on overlying archaeological deposits, since it is self-contained and detonated only at a charge necessary to remove bedrock to approximately the same width as the upper portion of the core (Peter Cava, PECO Energy, personal communication 1985). If a simple coring operation without associated grading operations is required, it can be expected that Dyrness' (1965) Class 3 (deeply disturbed) soil profile will result, but only in a very localized area. Likewise, although Bryant, Gehr, and Flenniken's (1982) Class 1, Class 2, and Class 3 (i.e., artifact breakage, displacement, and exposure) archaeological data loss will also likely occur, such losses will only be in a very localized area.

A rather dramatic example of the localized nature of the coring process was found in a section of one of the Limerick transmission lines (Zatz, Joiré, Hoffman, and Rast 1985). Because portions of this line were slated for the replacement of lattice support structures by new tubular steel poles in the same locations, several test units were placed within the confines (normally near the center) of the existing lattice structure, as well as surrounding them. In several cases, the resultant profiles showed little or no disturbance of any kind and, in one case, an undisturbed portion of a prehistoric archaeological site was revealed within such confines (Zatz, Joiré, Hoffman, and Rast 1985). Clearly, disturbances resulting from the coring operations in this case were quite localized.

### Installation of counterpoise system

Since no instances of the installation of a counterpoise system, either associated with extant or newly constructed support structures, were observed during the Limerick project, it is not possible accurately to evaluate the extent of disturbance to archaeological sites such activity causes. However, the fact that small trenches a minimum of 61 cm (24 in) in depth are excavated either with a plow or trencher implies that rather extensive, although relatively localized, disturbance can occur. This, of course, is especially true with regard to the relatively shallow upland sites in the Pennsylvania Piedmont. Accordingly, it may be prudent for planners to bear in mind the occasional need for such a system which has the potential to expand the area of direct effect some distance away from support structure locations. The installation of a counterpoise system will most likely result in Dyrness' (1965) Class 2 (slightly disturbed) and Class 3 (deeply disturbed) soil profiles and Bryant, Gehr, and Flenniken's (1982) Class 2 (artifact displacement) and Class 3 (artifact exposure) archaeological data loss.

### STRATEGIES OF ARCHAEOLOGICAL INVESTIGATION

It is important to note that the entire length of the Limerick transmission line right-of-way, regardless of support structure location, was subjected to Phase I identification/location survey. In addition, areas where temporary access roads were necessary were also subjected to Phase I survey. However, not all archaeological sites identified during Phase I were evaluated for National Register significance at the Phase II level. Sites subjected to Phase II were selected according to their location within the right-of-way in relation to proposed support structure locations or their relation to proposed access roads. Phase III data recovery was undertaken only where adverse effect to significant sites could not be avoided. These areas were limited, in all cases, to support structure locations and areas where access roads would adversely affect portions of significant archaeological sites. These investigative strategies are similar to those utilized by other researchers in conducting archaeological surveys in association with overhead transmission line rights-of-way (e.g. Office of Public Archaeology 1986a, 1986b; Weir 1986; Strauss 1987a, 1987b).

Of further importance is the fact that the majority of transmission line rights-of-way investigated during the Limerick Transmission Line Surveys consisted of previously existing right-of-way in which transmission lines and support structures were extant prior to the survey. Thus, the proposed lines and support structures were designed as replacements for previously existing facilities and, in some cases, as a new facility paralleling old line. As such, most of the surveyed rights-of-way were cleared when the existing lines were installed between the 1920s and 1960s, and many of the newly designed structures were slated for locations identical with or adjacent to the extant structure locations. Some support structure locations, however, were planned for new loci. As a result, it is important to realize that most of the surveyed areas had previously been subjected to many of the construction techniques discussed earlier in this paper. This circumstance is different from many similar surveys (e.g. Ranere and Hansell 1983; Newkirk and Bambrey 1984, 1985; Strauss 1987a, 1987b), in which the transmission line right-of-way was newly designed and, therefore, devoid of extant support structures.

In concert with the archaeological methods noted above, a wide variety of strategies was also employed to minimize effect to archaeological resources, significant or otherwise, and to beneficially accommodate schedules and logistical considerations in the construction of temporary access roads and coring operations for the construction of support structures. These strategies were implemented to help avoid further disturbance to archaeological sites in existing transmission line rights-of-way as a result of the new construction, and involved various levels of intensity, ranging from simple monitoring to full-scale archaeological excavation. These strategies are briefly described below.

#### Monitoring of right-of-way clearing and selective thinning activities

Vegetational clearing and thinning necessary to allow for the access of equipment to core and erect new support structures was undertaken during the project only after all Phase I and Phase II archaeological investigations had been completed. This meant that, at the time of the new clearing, all archaeological sites in the right-of-way had been identified and evaluated for significance. As a result, areas that required archaeological monitoring during clearing activities were previously identified, as were "voids" where monitoring would not be necessary. Moreover, in areas that contained archaeological sites, the clearing contractor was only permitted to undertake his work using hand tools such as chain saws and root cutters, and small mechanized equipment such as truck and chipper, all under close monitoring by the archaeological team.

The monitoring strategy employed during the initial vegetational clearing operation proved to be quite effective, since the archaeological team was able to maintain reasonable control over the techniques utilized for clearing by the contractor. While localized examples of Dyrness' (1965) Class 2, Class 3, and Class 4 (i.e., slightly disturbed, deeply disturbed, and compacted) soil profiles, and Bryant, Gehr, and Flenniken's (1982) Class 2 and Class 3 (i.e., artifact displacement and exposure) archaeological data loss probably occurred, instances of wholesale or widespread disturbance to an archaeological site during clearing activities were avoided.

#### Stripping of temporary access road rights-of-way

As noted previously, the rights-of-way of all temporary access roads, as well as the actual transmission line rights-of-way, were subjected to both Phase I survey and Phase II evaluation, as appropriate. This resulted in a level of confidence regarding site presence, absence, and/or significance in the access road rights-of-way similar to that of those in the transmission line rights-of-way. Since the coincidental occurrence of temporary access road rights-of-way and significant archaeological sites was present only in areas previously subjected to agricultural plowing, the strategy utilized after the completion of controlled surface survey was to excavate the necessary roadway cut to just above the interface of the plowzone and the underlying subsoil under the guidance of archaeological monitoring, with sufficient time granted for the archaeological team to shovel-scrape and expose by hand the underlying subsoil and any features or other archaeological deposits which might be revealed. In this fashion, long linear expanses of extant subsoil deposits associated with potentially significant archaeological sites were exposed, and the resultant information recovered prior to its disturbance. Once such data were recovered, the construction contractor was permitted to return, infill the cut with ballast rock, grade and/or asphalt as necessary, and proceed with construction of the support structures whose locations could then be serviced by the access road.

It is also important to note that a short-term site-protective strategy was employed at one of the archaeological sites subjected to the procedures discussed above. Due to the onset of inclement winter weather, data recovery at this site had to be suspended until spring, although the construction schedule for the necessary temporary access road could not accommodate a similar suspension. At the time of suspension of the archaeological work, five unexcavated or partially excavated archaeological features were exposed, and an additional 20 excavated features had been infilled with clean sand. To allow for the installation of ballast rock for construction of the roadway, one layer of one-half inch plywood and two layers of one-quarter inch fiberglass matting were laid down in the roadway cut, with the ballast rock deposited on top. Upon resumption of archaeological field work in the spring, and after the access road had been used for its intended purpose, a flat bucket gradall was used to remove the ballast rock and fiberglass from the cut. As had been hoped, no damage had been imparted to the archaeological features, and no loss of data occurred (Zatz, Joiré, Hoffman, and Rast 1985). That is, none of the archaeological features had experienced compaction or lateral displacement of any kind. It should further be noted that geo-synthetic filter fabric (Thorne 1989) and "crusher run" (i.e., crushed stone aggregate – Marquis 1989) have also been successfully used as archaeological site protective measures.

### Testing and excavation at support structure locations

During the initial Phase I survey, the entire extent of each transmission line right-of-way was subjected to surface reconnaissance, even though it was anticipated that, aside from areas necessitating the construction of access roads, the areas which would experience the greatest adverse effect would be support structure locations. Similarly, all potentially significant sites located at the Phase I level were subjected to Phase II surface or subsurface testing, or both, regardless of the site's location in relation to support structure placement. However, Phase III data recovery excavations were undertaken only at significant archaeological sites which coincided with support structure or access road locations which otherwise could not be avoided.

In nearly all cases, the Phase II subsurface testing at support structure locations consisted of controlled surface collection procedures in plowzone situations, followed by the judgmental placement of test units in areas of high artifact density; such tests measured up to 1.5×1.5 m (5×5 ft) in size, depending on site-specific conditions (Zatz, Joiré, and Hoffman 1984a). This was done both in cases where structures were planned for new locations and where new structures were planned to replace old, extant structures. In most cases, this standard strategy was adequate to evaluate site significance. However, in one case, a different strategy was utilized at the Phase II level, due to the presence of fresh, untreated, and potentially hazardous manure on the surface of the plowzone. In this case five areas slated for the construction of support structures were stripped of plowzone in a manner similar to that previously described for significant sites in temporary access road rights-of-way (Zatz, Joiré, and Hoffman 1984a). The only differences between this strategy and that used in temporary access road situations were that (1) roughly circular, localized structure locations, rather than linear swaths, were stripped of plowzone, and (2) the strategy was employed at the Phase II rather than the Phase III level of effort.

## CONCLUDING SUMMARY

In summary, the archaeological investigations associated with licensing activities of the Limerick Nuclear Generating Station has enabled a preliminary evaluation of PECO's construction techniques and policies as they interface with the prehistoric archaeological record in the Piedmont of southeastern Pennsylvania. This evaluation, although far from quantitative in nature, in turn has allowed for a rough ranking of the nature and extent of these construction techniques in terms of their potential to disturb archaeological sites. This ranking, summarized in Table 1, is as follows.

The initial clearing of overhead transmission line rights-of-way probably has the greatest potential for disturbing archaeological sites surficially and on a relatively wide horizontal scale. This potential stems largely from the fact that the precise nature and extent of effects to soils and archaeological sites stemming from such clearing activities are extremely difficult to quantify. While the nature and extent of such clearing is dependent on the specific conditions of the right-of-way, it seems clear that, in heavily vegetated areas, such activities can lead to more widespread grading and other land altering operations, resulting in Dyrness' (1965) Class 3 and Class 4 soil profiles (i.e., deeply disturbed and compacted) and Bryant, Gehr, and Flenniken's (1982) Class 1, Class 2 and Class 3 archaeological data loss (i..e, artifact breakage, displacement, and exposure). This also appears evident in the Pinelands of southern New Jersey, where Ranere and Hansell (1983) observed large expanses of "bare earth" where clearing activities had at least surficially disturbed the right-of-way through the heavily wooded landscape. Similarly, Strauss (1987b) observed areas of the New England/Hydro-Quebec transmission line right-of-way

**Table 1. Generalized ranking of construction techniques and potential disturbance**

| Degree of severity | Construction technique | Classes of soil disturbance* | Classes of archaeological data loss** | Characteristics |
|---|---|---|---|---|
| Severe | clearing of R.O.W. | 3,4 deeply disturbed, compacted | 1,2,3 artifact breakage, displacement, exposure | horizontally widespread, perhaps mostly surficial, but difficult to quantify and isolate |
| Severe | construction of temporary access roads | 2,3 slightly disturbed, deeply disturbed | 1,2,3 artifact breakage, displacement, exposure | confined to a specific area that can be isolated, but disturbed to subsoil |
| Moderately severe | installation of counter-poise system | 2,3 slightly disturbed, deeply disturbed | 2,3 artifact displacement, exposure | somewhat localized, not always necessary but disturbed to subsoil |
| Severe, but very localized | uprooting of stumps, coring for footings | 3 deeply disturbed | 1,2,3 artifact breakage, displacement, exposure | very localized, easy to isolate |
| Not severe | selective thinning of vegetation | 2 slightly disturbed | 1,2 artifact breakage, displacement | mostly surficial in extent (e.g., tire ruts) |

*Dyrness (1965).
**Bryant, Gehr, and Flenniken (1982).

where grading, plowing, or infilling had occurred, leaving "small pockets of intact soil." However, it is equally evident that many areas need no clearing, as evidenced by the large expanses of open, cultivated fields in the project area of southeastern Pennsylvania. Similarly, transmission line design and construction through vast expanses of desert areas, such as experienced in the Gonder Line 1 (Newkirk and Bambrey 1984) and Mona Line 1 (Newkirk and Bambrey 1985) rights-of-way of western Utah and eastern Nevada, presumably also require no clearing activities. The key factor in initial clearing, obviously, is the degree to which the immediate area is vegetated. Accordingly, it is of utmost importance in areas of heavy vegetation to conduct archaeological reconnaissance surveys prior to right-of-way clearing if disturbance to the archaeological record is to be minimized or avoided.

Temporary road construction necessary for access in some areas is also a potentially significant threat to the integrity of archaeological sites, most likely resulting in Dyrness' (1965) Class 2 (slightly disturbed) and Class 3 (deeply disturbed) soil profiles and Bryant, Gehr, and Flenniken's (1982) Class 1, 2, and 3 archaeological data loss (i.e., artifact breakage, displacement, and exposure). However, since such roads are designed and engineered for specific purposes, the areas of potential disturbance are readily identifiable by perusing design plans. In this sense, the areas of disturbance are relatively localized and specific in nature, although the precise nature and extent of the last grading operation is probably less localized than the actual excavation of the sub-base trench. Nevertheless, if careful interfacing of design considerations and archaeological preservation is followed, the avoidance of disturbance to archaeological sites, or at least portions of such sites, should be a relatively simple matter.

Other activities associated with the construction of support structures also have the potential to disturb archaeological deposits, but these activities are of a much more localized nature than those previously noted. The uprooting of large tree stumps during the clearing process can severely disturb archaeological sites, resulting in Bryant, Gehr, and Flenniken's (1982) Class 1, Class 2, or Class 3 (i.e., artifact breakage, displacement and exposure) archaeological data loss; PECO, however, prefers in most cases that stumps be cut off flush with the ground surface (PECO S-7080-B 1983). The coring of holes to accommodate concrete support structure footings may also destroy archaeological deposits but again, the area of disturbance frequently is extremely localized, normally between six and ten feet in diameter. The fact that undisturbed soil profiles were observed during the Limerick survey within the confines of an extant four-cornered lattice-type structure certainly attests to the localized nature of this type of disturbance. Blasting necessary when footings are required in areas of bedrock should have virtually no effect on archaeological deposits, since presumably no such deposits are present (due to the presence of bedrock), and such blasting is self-contained within the footing core. Finally, the necessity of counterpoise systems at some support structure locations can, of course, result in some damage to archaeological sites, perhaps resulting in Bryant, Gehr, and Flenniken's (1982) Class 2 and Class 3 (i.e., artifact displacement and exposure) archaeological data loss, but again, it is relatively localized in extent. However, the fact that PECO specifications (PECO S-7080-G-1983) mandate that such systems be installed at a depth of 61 cm (24 in) or more necessitates that careful archaeological planning and survey be conducted of areas wider in extent than the footprint of the structure if disturbance to the archaeological record is to be minimized or avoided.

Selected thinning and pruning, unless inclusive of ground-altering landscaping activities, is the activity associated with transmission line construction least likely to seriously disturb archaeological deposits. Such thinning is normally done with hand tools and perhaps a truck and chipper, and normally is confined to the upper reaches of vegetation which have begun to encroach into the defined "danger zone." The most extensive disturbance to archaeological sites resulting from this operation is likely to be tire ruts resulting from the truck and chipper traversing soft or muddy ground. Such activities may result in Dyrness' (1965) Class 2 (slightly disturbed) soil profiles, and Bryant, Gehr, and Flenniken's (1982) Class 1 and Class 2 (i.e., artifact breakage and displacement) archaeological data loss.

In closing, the management of archaeological resources potentially affected by transmission line construction has become a more widespread planning concern in the last decade throughout the United States and Canada (e.g. Weir 1986; Peters 1986). The archaeological aspect of the licensing activities of the Limerick Nuclear Generating Station is a noteworthy addition to the growing list of such management and planning activities in the electric utility industry. Furthermore, the Limerick transmission line rights-of-way themselves are particularly important in that the area of southeastern Pennsylvania through which the transmission lines traverse is currently experiencing an extremely high rate of growth and land use, with the concomitant rapid decrease in archaeologically undisturbed areas. Consequently, the extant transmission line rights-of-way associated with the Limerick Nuclear Generating Station represent some of the few remaining large-scale linear expanses of landscape in the southeastern Pennsylvania Piedmont which, although subject to some disturbance in the past, nevertheless remain relatively undisturbed. As a result, and with PECO's demonstrated commitment to the proper management of archaeological resources under its purview, archaeological sites recorded during the Limerick project are likely to remain relatively protected well into the future.

## ACKNOWLEDGEMENTS

The PECO Energy personnel who contributed to the information contained in this article are heartily thanked for their continuing enthusiasm and support during the many years of the project. Principal among these are Walter Payne, former Manager of the Berwyn Transportation Center Survey Office and a notable avocational archaeologist, whose concern about the effects of the Limerick construction project on prehistoric archaeological resources was the principal impetus in making this study possible. Similarly, the efforts of D.S. Frieman, Manager of the Real Estate Department, and Thomas Clime, former Supervisor of the Property Management Section, are acknowledged and appreciated. Both Mr. Frieman and Mr. Clime have maintained long-term commitments to balancing PECO's primary mission of adequately meeting the energy requirements of the Philadelphia region's burgeoning population with concerns for the environment, and their interest in the prehistoric archaeology of the Lower Schuylkill River Valley is a logical and sustained extension of that commitment. In addition, Stanley V. Heyer, Jr., Supervising Engineer of PECO's Transmission Branch; Peter Cava, Supervisor of the Construction Branch; and Anthony L. Milone, Senior Engineer of the Transmission Branch, were all instrumental in the successful completion of the project. Mr. Heyer kindly kept the project team abreast of evolving modifications to PECO's Standard Specifications for the Construction of Transmission Lines, thereby enabling the successful interfacing of construction and archaeological concerns. Mr. Cava and Mr. Milone provided the necessary logistical coordination during all stages of field work so that archaeological, engineering, right-of-way, and construction timetables could be met successfully. Finally, the author would like to thank Nick Chevancee and John M. Bridges, both of Western Area Power Administration in Golden, Colorado, and an anonymous reviewer for making suggestions that greatly improved the paper.

Several former employees of JMA assumed supervisory positions on various aspects of the project, and were instrumental in its successful completion. Especially noteworthy is Karyn L. Zatz, who served as Field Supervisor throughout the various field seasons of the project. Assisting Ms. Zatz in field supervisory roles at various times were Kenneth M. Joiré, Robert F. Hoffman, and Michael J. Rast, and all of their respective efforts are greatly appreciated. Sincere thanks are also extended to Margy Schoettle, who cheerfully suffered through the word processing of several versions of this manuscript.

This paper represents a revised version of a paper originally presented at the Edison Electric Institute National Land Management Workshop, August 26–29, 1991, at Conowingo, Maryland.

## REFERENCES

Brown, G.W. 1975. The impact of timber harvest on soil and water resources. Extension Bulletin No. 827. Oregon State University, Corvallis, Oregon.

Bryant, R., E. Gehr, and J. Flenniken. 1982. The effects of yarding operations on archeological sites. Report prepared for the USDA Forest Service, Portland. Professional Analysts, Eugene, Oregon.

DeBloois, E.I., D.F. Green, and H.G. Wylie. 1975. A test of the impact of pinyon-juniper chaining on archaeological sites. In: The Pinyon-Juniper Ecosystem: A Symposium. College of Natural Resources, Utah State University, Logan, Utah. pp. 153–161.

Dyrness, C.T. 1965. Soil surface condition following tractor and high lead logging in Oregon Cascades. Journal of Forestry, 63: 272–275.

Fredriksen, R.L. 1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. USDA Forest Service Research Paper PNW-104.

Froehlich, H. 1976. The influence of different thinning systems on damage to soils and trees. Department of Forestry, Oregon State University, Corvallis, Oregon.

Gallagher, J. 1978. Scarification and cultural resources: An experiment to evaluate serotinous lodgepole pine forest regeneration techniques. Plains Anthropologist, 23(82): 289–299.

Garrison, G.A. and R.S. Rummell. 1951. First-year effects of logging on ponderosa pine forest range lands, Oregon and Washington. Journal of Forestry, 49: 708–713.

Gilbert/Commonwealth, Inc. 1988. Route analysis report for the Watermill-West Levee 345 kV transmission line. Report prepared for Texas Utilities Electric Company. Gilbert/Commonwealth, Inc., Jackson, Michigan.

Kingsley, R.G., J.A. Robertson, and D.G. Roberts. 1990. The archeology of the lower Schuylkill river valley in southeastern Pennsyvlania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

Klock, G.O. 1975. Impact of five postfire salvage logging systems on soils and vegetation. Journal of Soil and Water Conservation, 30: 78–81.

Marquis, G.E. 1989. Placement of aggregate on archeologically sensitive roads. Paper presented at the National Utility Land Management Workshop sponsored by the Edison Electric Institute, Sugarloaf Mountain, Maine, September 25–27, 1989.

Newkirk, J.A. and L.H. Bambrey. 1984. A cultural resources and paleontological survey of the 230 kV Intermountain-Gonder Line 1, vol. 1. Report prepared for Intermountain Power Agency. Gilbert/Commonwealth, Inc., Englewood, Colorado.

Newkirk, J.A. and L. Hackett Bambrey. 1985. A cultural resources and paleontological survey of the 345 kV intermountain-mona line 1 right-of-way and access roads. Report prepared for Intermountain Power Agency. Gilbert/Commonwealth, Inc. Englewood, Colorado.

Office of Public Archaeology. 1986a. New England/Hydro-Quebec phase II transmission facilities cultural resource survey, volume 1: New Hampshire. Report prepared for New England Power Company. Office of Public Archaeology, Boston University.

Office of Public Archaeology. 1986b. New England/Hydro-Quebec phase II transmission facilities cultural resource survey, volume 2: Massachusetts. Report prepared for New England Power Company. Office of Public Archaeology, Boston University.

Patric, J.H. 1976. Effects of wood products harvest on forest soil and water resources, with emphasis on clearcutting in moist climates. Unpublished manuscript on file, USDA Forest Service, Portland, Oregon.

Peters, J.H. 1986. Transmission line planning and archaeological resources: A model of archaeological potential for southwestern Ontario. In: Papers of the London Conference 1985, Archaeological Consulting in Ontario. W.A. Fox, ed. Occasional Papers No. 2 of the London Chapter, Ontario Archaeological Society, Inc. pp. 19–27.

Philadelphia Electric Company (now PECO Energy). 1968. Policy and program for improving appearance of overhead transmission lines. Manual published by the Philadelphia Electric Company.

Philadelphia Electric Company (now PECO Energy). 1983. Standard specification (S-7080) for the construction of transmission lines along private rights of way (Sections S-7080-B, clearing of right of way, and S-7080-G, installation of counterpoise or ground rods). Specifications published by the Philadelphia Electric Company.

Philadelphia Electric Company (now PECO Energy). 1986. Standard specification (S-7080) for the construction of transmission lines along private rights of way (Sections S-7080-C, construction of foundations, S-7080-D, erection of towers, and S-7080-E, erection of steel poles). Specifications published by the Philadelphia Electric Company.

Ranere, A.J. and P. Hansell. 1983. An approach to determining site distributions in the Pine Barrens: power line surveying. In: The 1983 Middle Atlantic Archaeological Conference Proceedings. J. Evans, ed. pp. 90–99.

Ruth, R.H. 1967. Silvicultural effects of skyline crane and high-lead yarding. Journal of Forestry, 65: 251–255.

Steinbrenner, E.L. and S.P. Gessel. 1955. The effect of tractor logging on physical properties of some forest soils in southwestern Washington. Soil Science Society of America Proceedings, 19: 572–576.

Strauss, A.E. 1987a. Cultural resources survey of the relocated structure locations for the Hydro-Quebec (phase II) project, volume 1: New Hampshire. Report prepared for New England Power Company. Office of Public Archaeology, Boston University.

Strauss, A.E. 1987b. Cultural resources survey of the relocated structure locations for the Hydro-Quebec (phase II) project, volume 2: Massachusetts. Report prepared for New England Power Company. Office of Public Archaeology, Boston University.

Thorne, R.M. 1989. Filter fabric: A technique for short-term site stabilization. Archaeological Assistance Program, Technical Brief No. 1, U.S. Department of the Interior, National Park Service.

Weir, D.J. 1986. Cultural resource management approach utilized for the Intermountain Power project, Utah and Nevada. Paper presented at the Third National Conference on Cultural Resource Management in the Electric Utility Industry, St. Louis, Missouri.

Zatz, K.L. 1984. A descriptive report of an archeological investigation for the 220-62 transmission line right-of-way in association with the Limerick nuclear generating station, Montgomery and Chester Counties, Pennsylvania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

Zatz, K.L., K.M. Joiré, and R.F. Hoffman. 1984a. A descriptive report of an archeological investigation for the 220-60 transmission line right-of-way in association with the Limerick nuclear generating station, Montgomery and Chester Counties, Pennsylvania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

Zatz, K.L., K.M. Joiré, and R.F. Hoffman. 1984b. A descriptive report of an archeological investigation for the 220-61 transmission line right-of-way in association with the Limerick nuclear generating station, Montgomery and Chester Counties, Pennsylvania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

Zatz, K.L., K.M. Joiré, R.F. Hoffman, and M.J. Rast. 1985. A descriptive report of an archeological investigation for the 220-63 transmission line right-of-way in association with the Limerick nuclear generating station, Montgomery and Chester Counties, Pennsylvania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

Zatz, K.L., J.A. Robertson, and T.L. Struthers. 1989. A descriptive report of an archeological investigation for the 5031 transmission line right-of-way in association with the Limerick nuclear generating station, Montgomery County, Pennsylvania. Report prepared for the Philadelphia Electric Company. John Milner Associates, Inc., West Chester, Pennsylvania.

## *BIOGRAPHICAL SKETCH*

***Daniel G. Roberts***

*Cultural Resources Department, John Milner Associates, Inc., 309 North Matlack Street, West Chester, PA 19380, USA*

Daniel Roberts is Vice President and Director of the Cultural Resources Department at John Milner Associates, Inc., a cultural resources and historical preservation consulting firm headquartered in West Chester, Pennsylvania. He is an archaeologist by training and profession, having received his Bachelor's degree from Beloit College in 1969 and his Master's degree from Idaho State University in 1976, both in anthropology. His professional interests focus on the historical archaeology of the mid-Atlantic region, and he and his colleagues at John Milner Associates have served as consultants to numerous private and public clients for more than 20 years. Mr. Roberts is the co-author of *The Buried Past: An Archaeological History of Philadelphia* (University of Philadelphia Press, 1992).

# Unanticipated Discovery of Cultural Resources During Pipeline Construction: Two Case Studies

**Craig S. Smith**

The unexpected discovery of cultural resources has the potential to cause serious delays during pipeline construction. It is important that a plan for dealing with unanticipated discoveries of cultural resources during construction be submitted and approved by the regulatory agencies prior to construction. Discoveries can be handled in many different ways. A traditional approach requires all ground-disturbing activities to stop in the vicinity of the discovery until all mitigation data recovery excavations are completed. Alternatively, to eliminate the possibility of delays, except for the discovery of human remains, trench inspection by an archaeologist has been used successfully. The pipeline company agrees to conduct no more than a specified level of effort of investigations following construction, depending what is found in the trench. In exchange, discoveries in the pipeline trench will be recorded, but construction will not be stopped due to the discoveries; thus there will be no loss of construction time.

*Keywords*: Cultural resources, unanticipated discoveries, pipeline construction, archaeology, trench inspection, construction monitoring

## INTRODUCTION

Properly dealing with cultural resources-prehistoric and historic sites and artifacts-is often one of the major environmental concerns in planning and permitting pipeline construction in the United States. These resources need to be considered early in the planning process to limit the possibility of delays in construction. The steps required by Section 106 of the National Historic Preservation Act of 1966 (NHPA) and implementing regulations (36 CFR 800) need to be followed in the planning process for projects crossing federal lands or requiring federal permits. The following steps are typical in the preconstruction planning process.

The first step is to consult with the regulatory agencies including the State Historic Preservation Offices (SHPOs) and any federal agencies such as the Federal Energy Regulatory Commission (FERC), Bureau of Land Management (BLM), and U.S. Forest Service (USFS) to determine whether cultural resources studies are necessary and to develop a scope of work. Because further studies usually are required, the next step consists of a literature review and file search to obtain information on previous cultural resource investigations in the area and previously recorded cultural resource sites. Following the literature review, an on-the-ground inspection of the right-of-way using pedestrian archaeological inventory techniques is completed. All prehistoric and historic sites encountered during the inventory are recorded. The sites are then evaluated as to their eligibility for the National Register of Historic Places (NRHP). For many sites, especially those with prehistoric remains, this evaluation usually requires test excavations to determine the kinds and extent of the buried remains. Archival research is often conducted to document the historic events, themes, individuals, construction techniques, and/or architectural features associated with historic sites. Sites found within the right-of-way that may be affected by construction are evaluated as either eligible or not eligible for the NRHP. The sites determined not eligible for the NRHP are eliminated from further consideration.

Project effects to sites determined eligible for the NRHP are then assessed. Eligible sites that may be affected by construction activities can be avoided by reroutes or relocation of project facilities and construction areas. If avoidance is not feasible, a treatment plan is prepared to detail the measures to mitigate the effects to the sites. These mitigation measures may include reducing the width of the right of way; barricading, flagging, and fencing; matting or padding a site to minimize compaction by heavy equipment; documenting sites according to the standards of the Historic American Building Survey (HABS) or the Historic American Engineering Record (HAER); and archaeological data recovery. Data recovery through excavation is commonly used on sites within the right-of-way that contain remains that could provide information to address research issues concerning the prehistory or history of an area. These mitigation measures are generally completed prior to the start of construction.

For larger pipeline projects subject to federal permits and approvals, a Programmatic Agreement (PA) is often the vehicle which federal agencies achieve compliance with Section 106 of the NHPA. The PA details the procedures and time frames to complete the various steps to reach cultural resource clearance for a project and is signed by the regulatory agencies involved with the project and sometimes the project proponent.

Though involved and time consuming, these steps in the Section 106 process to obtain cultural resource clearance for a project can be followed in a fairly cookbook fashion, and the costs and time to implement them can be anticipated during the project planning phase. The most important consideration is that enough time be allowed to complete the process before the start of construction. In contrast, unanticipated discoveries of cultural resources or human remains during construction are an unknown in terms of time and cost and may cause extensive delays in construction. These costs and delays are difficult to anticipate in the planning process. Generally, a plan for dealing with unanticipated discoveries during construction is approved by the regulatory agencies prior to construction as outlined in Section 800.11 of the implementing regulations of the NHPA. This plan is a step-by-step guide to handling the discoveries and should be as comprehensive as possible to minimize delays. Because time is of the essence during construction, contact persons including pipeline, construction, and agency personnel, environmental inspectors, and archaeologists should be clearly identified with phone and fax numbers. A detailed plan is especially critical when the agencies require an archaeological monitor during construction grading and trenching in probable high site density areas since a trained archaeologist is better able to recognize unanticipated discoveries. Handling unanticipated discoveries without a plan requires more complex and time consuming procedures including allowing the Advisory Council on Historic Preservation to comment.

The remainder of this paper provides two case studies from the state of Wyoming concerning unanticipated discovery plans and the handling of archaeological discoveries. For the first case study, a traditional approach was followed for the unanticipated discovery plan, which required all ground-disturbing activities to stop in the vicinity of the discovery until all mitigation data recovery excavations were completed. For the second case study, the pipeline company agreed in the treatment plan to inspection of the trench and graded right-of-way during construction. The company agreed to sponsor a pre-established level of excavation of sites found during construction after the pipe was in the ground. This agreement to complete excavations following construction based on the remains observed in the trench eliminated the possibility of construction delays, except in the event of discovery of human remains. The discovery of human remains necessitates the implementation of special procedures including halting construction in the immediate area; contacting the county sheriff/coroner to determine the modernity of the remains; and it the remains are not modern, meeting with the SHPO, the landowner or land-managing agency, and concerned Native American groups to come to consensus agreement concerning the respectful treatment of the remains. For both of these approaches, the plan had to be acceptable to the federal agencies and the SHPO prior to construction.

## CASE STUDY ONE

The first case involved the construction of a loop of the Northwest Pipeline in southwest Wyoming (Fig. 1). The lead federal agency for the project was the FERC with other agencies including the SHPO and BLM. After completing all the preconstruction cultural resource tasks (McNees Harding, McClelland, et al. 1993; McNees, McClelland, Lowe, Marmor, Schneider, and Smith 1994), cultural resource clearance was obtained for construction provided measures in the treatment plan were implemented. Among the measures in the treatment plan was a requirement that certain areas be monitored by an archaeologist during grading and trenching. These areas were portions of the project deemed by the agencies to have a strong possibility of containing previously undiscovered buried cultural resources and all lands administered by the BLM. The treatment plan also included a detailed Unanticipated Discoveries Plan (Foster Wheeler 1995), which was to be followed in the event that cultural resources were discovered during the archaeological monitor. The plan stipulated that the Chief Environmental Inspector stop work within 150 m of the discovery, have the archaeologist assess the significance of the find, and notify the company, FERC, SHPO, and BLM if the find was on BLM land. If the cultural resource appeared significant, the notification would include a scope of work for evaluating significance and a request to immediately implement the scope of work. Following completion of fieldwork, a written report would be prepared and submitted. If the resource was determined to be

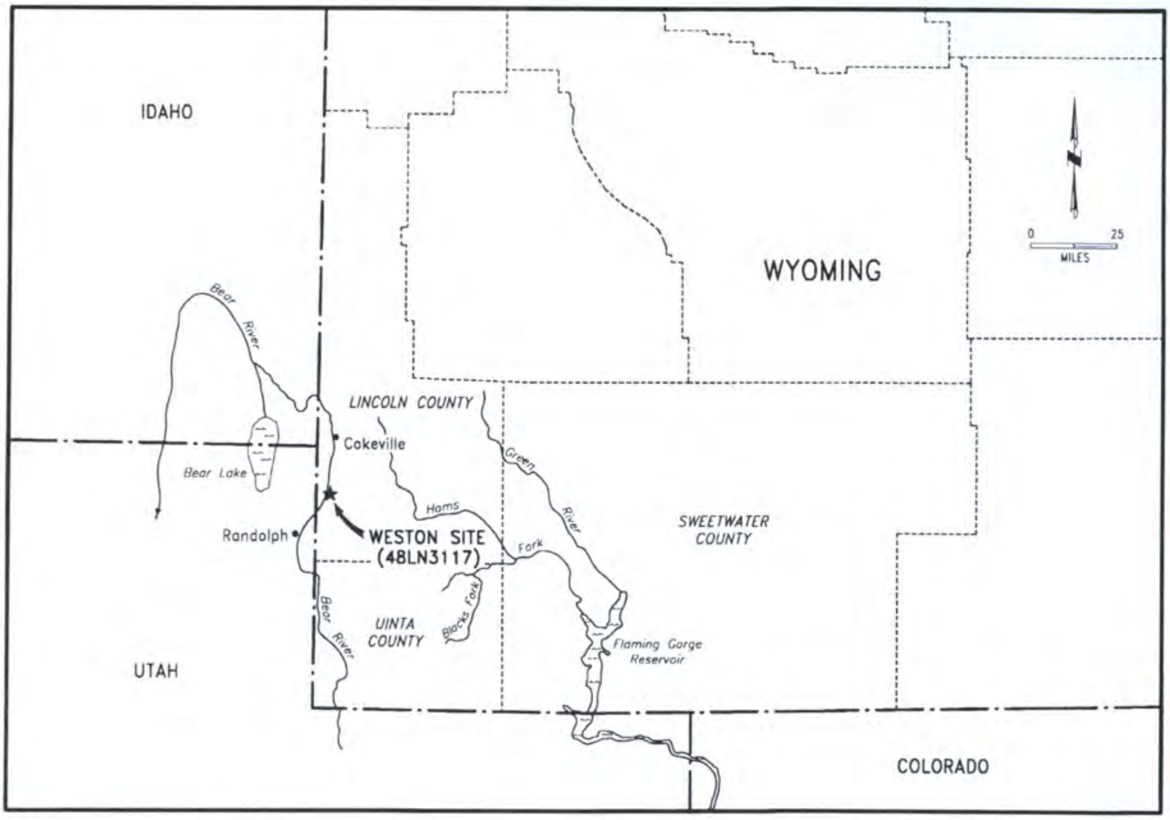



Fig. 1. Location of the Weston site on the Northwest Pipeline system expansion project in southwest Wyoming.

significant, a data recovery plan would also be prepared and submitted outlining the recommended form, scope, and research objectives for mitigating the impacts to the site, typically through archaeological excavations. Implementation of the data recovery plan would then proceed after authorization from the agencies. After completion of the data recovery excavations or other mitigation activities, pipeline construction would be authorized through the area.

On 24 August 1995, during the archaeological monitoring of construction right-of-way and staging area topsoil stripping on the terrace immediately east of the Bear River on private land, archaeologists discovered approximately 10 circular areas of charcoal-stained sediment representing five prehistoric hearths, as well as historic artifact clusters (Fig. 2). The hearths were found throughout the construction ROW in the areas that had been the most deeply graded (Fig. 3). These features were found in an area not previously considered a site due to the absence of any surface manifestation, though the area was scoped as having a high potential for buried remains early in the process. On identification of the site (named the Weston site), ground-disturbing activities were halted within 150 m of the discovered remains, and the procedures outlined in the Unanticipated Discoveries Plan were implemented. Within a day of the discovery, the site was recorded and an initial report was submitted to the agencies. Based on the description of the material already encountered at the site, the FERC and SHPO determined the site to be eligible for the NRHP. They requested that a treatment plan be prepared that would address appropriate measures to mitigate existing impacts, as well as further impacts to the site.

Fig. 2. Examination of an unanticipated discovery of a prehistoric hearth feature during right-of-way grading.

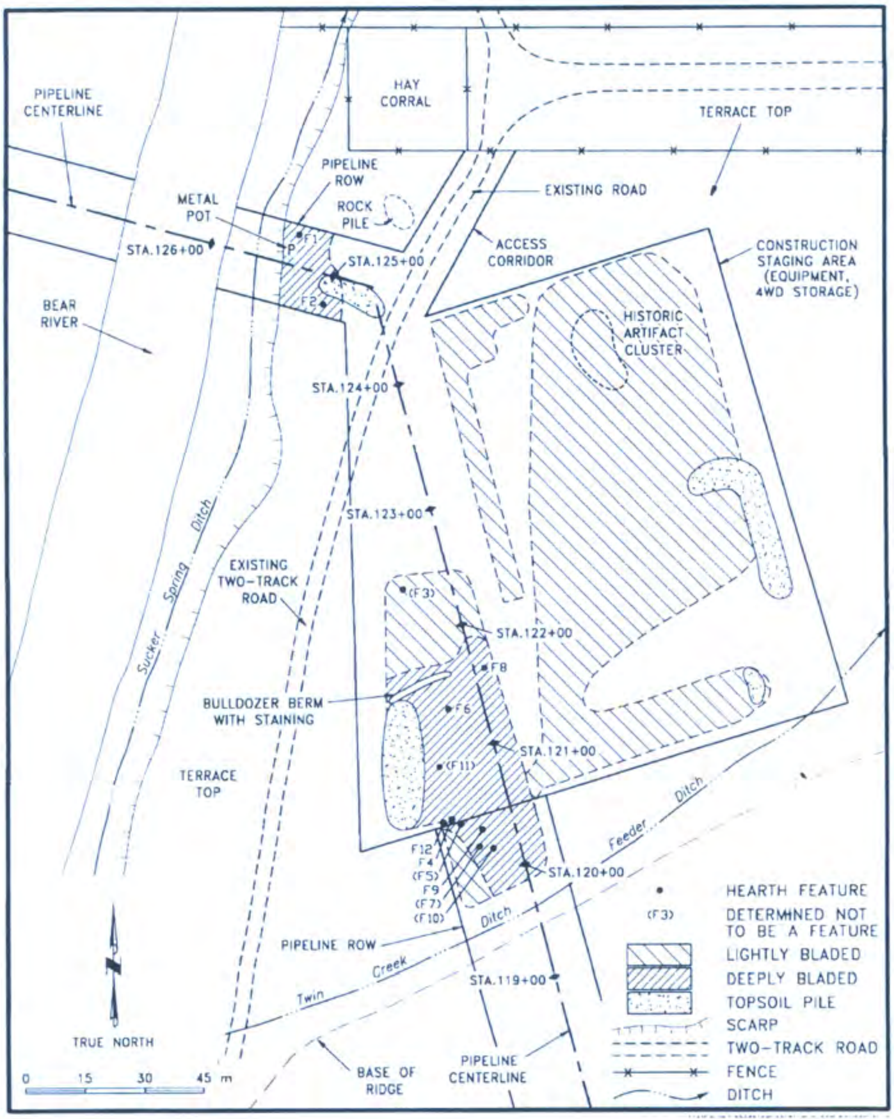



Fig. 3. Construction right-of-way and staging area with location of cultural remains found during right-of-way grading.

Within a week of the initial discovery and within a day of the agency request, a treatment plan was submitted to the FERC and SHPO (McNees and Smith 1995). The Treatment Plan included a research design and methods and proposed a two-phased approach to the data recovery excavations. Phase 1 would include the excavations of the features exposed during the grading and the testing of all additional areas along the terrace adjacent to the river requiring disturbance to complete pipeline construction. Phase 2 would consist of block excavations in areas where significant cultural remains were encountered during the Phase 1 investigations. The Treatment Plan was approved by the FERC, SHPO, and Advisory Council on Historic Preservation on 6 September 1995, five days after it was submitted.

Fieldwork commenced immediately on 6 September 1995. The Phase 1 investigations consisted of 21 test units totaling 52 m$^2$, 99 shovel tests, and five backhoe trenches totaling 100 m in length (Fig. 4). The backhoe trenches were placed along the centerline of the proposed pipeline and across the proposed location of a pit to hold spoil excavated from the river in the staging area. The backhoe trenches served as a means to examine a more deeper and larger area than would have been possible with only the hand excavations. The 30×30 cm shovel tests were systematically placed on a 10×10 m grid across the staging area and pipeline right-of-way. The shovel tests were used to explore the area for the most concentrated remains. The 1×1 m test units were excavated to assess additional areas that would be disturbed due to pipeline construction, to salvage the exposed features, and to investigate areas where shovel tests had positive results. The results of the Phase 1 investigations indicated that significant remains were present within the pipeline right-of-way. These remains consisted of hearth features, heat-altered rock, large quantities of artifacts, and charcoal-stained sediment, all indicating that the area was extensively used during prehistoric times.

Because of the significant remains encountered in the pipeline right-of-way, the FERC and SHPO required that

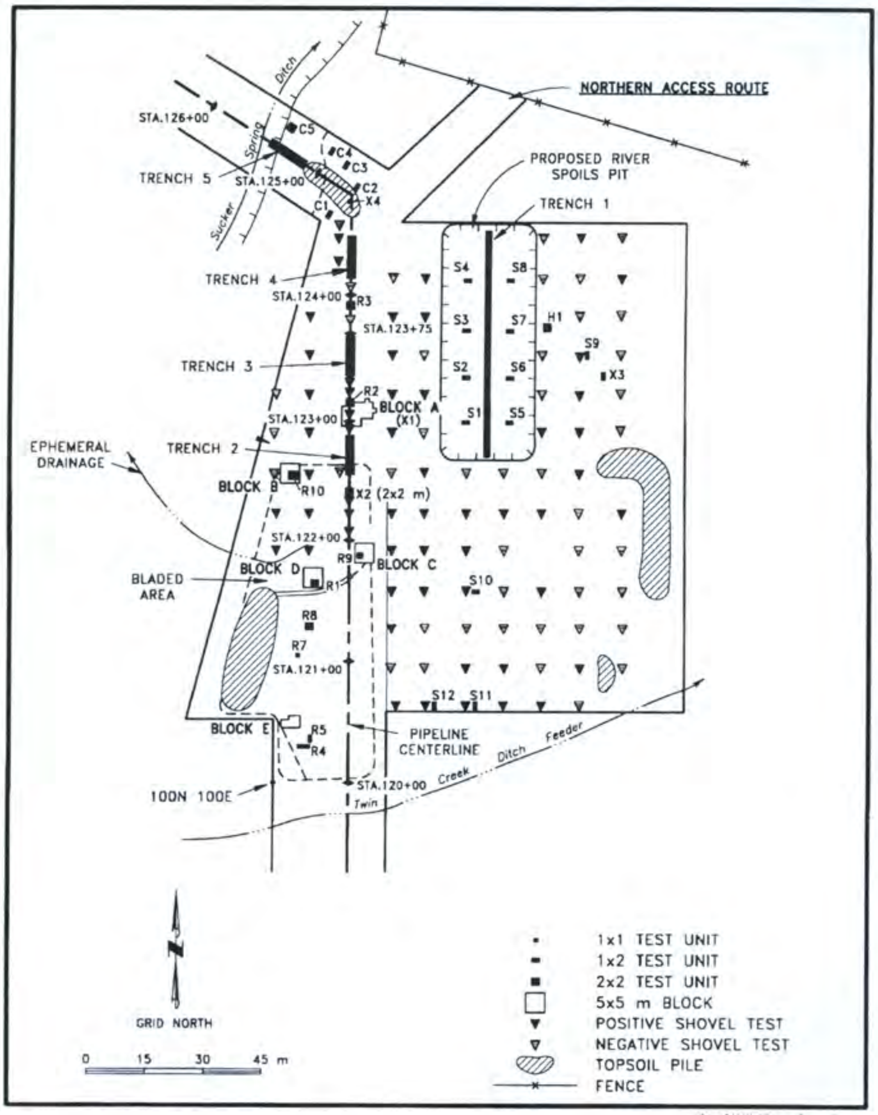



Fig. 4. Location of data recovery investigations following discovery.

four 5×5 m blocks (Blocks A-D) be excavated for the Phase 2 investigations. One of the blocks (Block A) was expanded an additional 16 m$^2$ to incorporate a housepit feature found during the excavations. A total of 116 m$^2$ was excavated during the Phase 2 investigations. The blocks were placed over test units containing hearth features or other significant remains. Among the extensive remains recovered from the excavations of the blocks were a variety of features including a housepit (an excavated basin that may have had a superstructure), hearth basins, and heat-altered rock concentrations; lenses of heavily charcoal-stained sediment; over 100 flaked stone tools including 28 projectile points of various types and over 13,000 pieces of debitage; over 6,000 bone specimens of at least 11 different taxa including bison, pronghorn, jackrabbit, cottontail, ground squirrel, bird, fish, and frog/toad; ceramic sherds; a stone disk bead; and two pendant fragments. A profile of one of the block walls showing the complexity of the site deposits is provided in Fig. 5.

Overall, the data recovery excavations at the Weston site produced evidence of numerous extensive prehistoric occupations along the Bear River (McNees, Schneider, McClelland, Harding, Lowe, and Smith 1996). The occupations ranged in age from approximately 4,000 years ago to about 100 years ago. Throughout its history, the site served as a residential base camp from which both the rich resources of the Bear River riparian zone and the upland resources of the southern Overthrust Belt were exploited. General domestic activities evident for every occupation at the site include the procurement, preparation, and/or consumption of wide range of animal taxa, maintenance and manufacture of flaked stone tools, and other small-scale craft and manufacture activities. Some of the occupations focused on activities such as root and seed procurement, processing, and consumption; bone grease manufacture; and more intensive biface manufacture. Many of the excavated features from the later occupations are interpreted as being large root-baking pits. One of the

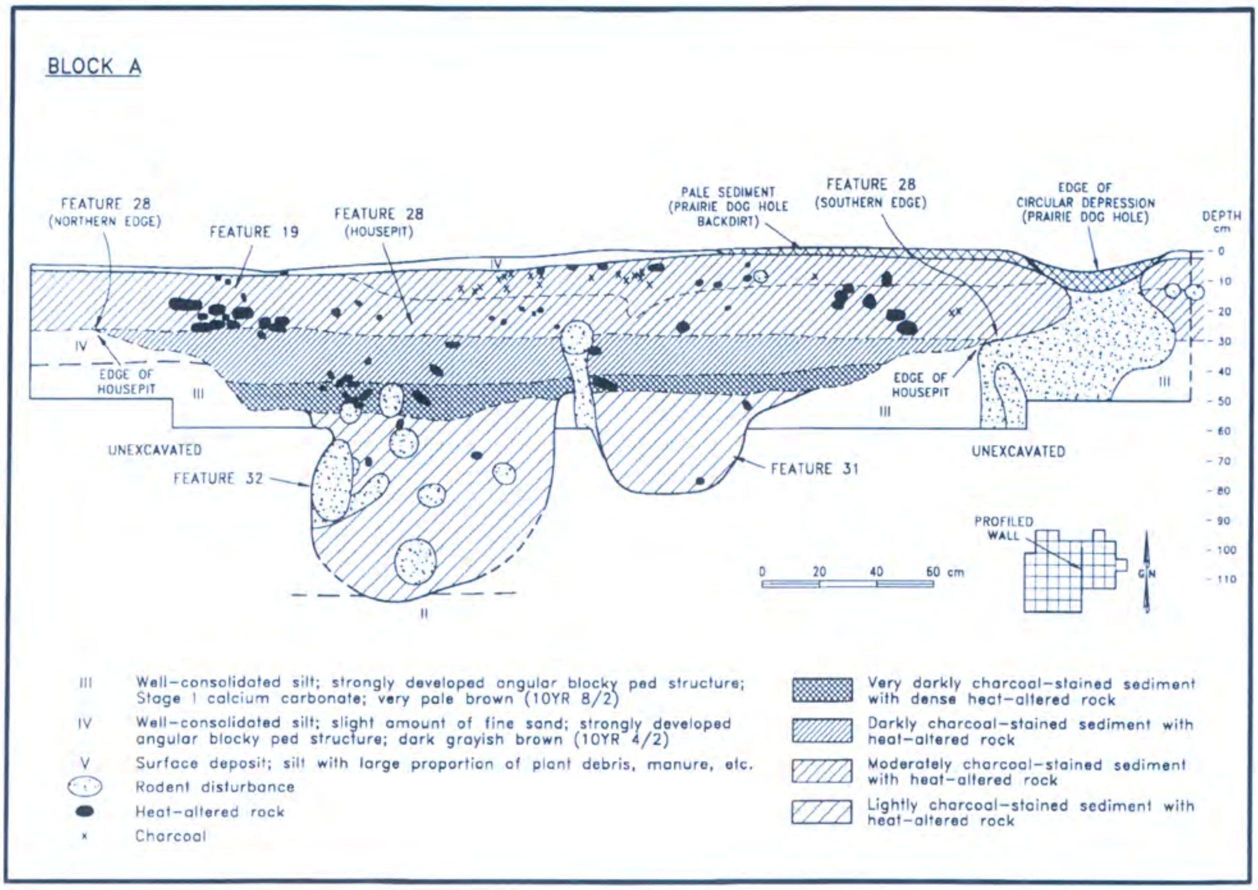



Fig. 5. Stratigraphic profile of one the excavation blocks showing complexity of site deposits and housepit.

more significant finds at the site was the housepit dating to one of the earlier occupations. The excavations at the site provided a wealth of new information on how the prehistoric inhabitants lived and used the upper Bear River area.

Data recovery excavations at the site were conducted from dawn to dark by a crew of up to 20 archaeologists from 6 September to 2 October 1995. After receiving a preliminary report on 2 October 1995, FERC and SHPO authorized construction to proceed on 4 October 1995. Pipeline construction in the portion of the route containing the site was delayed approximately five weeks including time for agency approval of the various stages in the investigations, time for writing the summary reports and treatment plan, and time for conducting the extensive Phase 1 and 2 data recovery excavations at a significant and complex site. Because a detailed Unanticipated Discoveries Plan was approved and in place prior to construction and due to the impressive effort of all involved, the delay in construction was kept to a minimum. Encountering such a significant site could have resulted in much longer delays. However, the discovery did cause a delay and skip in construction which added to the total costs of construction in addition to the extra costs for the archaeological compliance investigations. These costs could not be anticipated in the planning process prior to construction.

## CASE STUDY TWO

Another method which eliminates the possibility of construction delays resulting from unanticipated archaeological discoveries other than the discovery of human remains has worked successfully on larger pipeline construction projects. In this approach, the pipeline company agrees to have an archaeologist inspect the entire pipeline trench and graded right-of-way during construction and to conduct no more than a specified level of data recovery investigations following construction, depending on what was found in the trench. This method has benefits for both the pipeline company and the archaeology. It eliminates the possibility for expensive construction delays due to cultural resource discoveries during construction, and the company is able to budget the maximum costs for archaeology prior to construction. This approach also reduces the possibility of not being able to put the pipeline in service on schedule resulting in the lost of revenues which could be extensive. For the archaeology, the opportunity to examine the trench provides an ideal archaeological discovery technique where a deeper and more extensive cross section of deposits are examined than what normally would be probed. Additionally, the archaeologists can select the best sites discovered in the trench and excavate them without the pressures of the ongoing pipeline construction schedule.

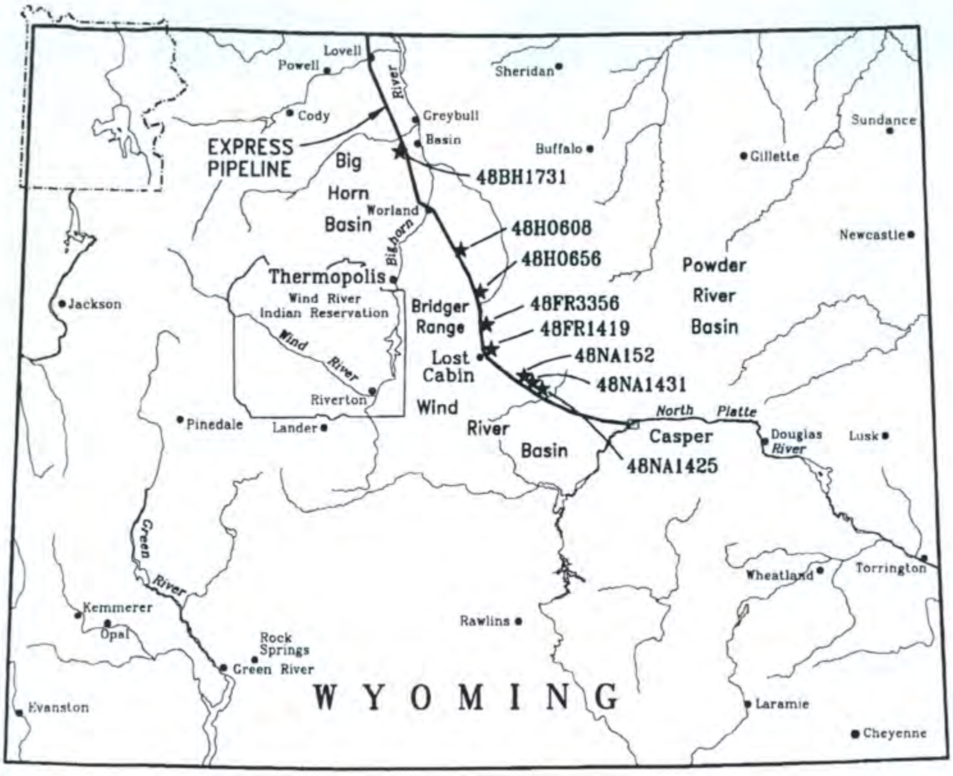



Fig. 6. Location of the Express Pipeline and sites excavated during preconstruction data recovery.

The second case study involved the construction of a 330 km Express Pipeline in northern and central Wyoming (Fig. 6). The lead federal agency was the BLM with other cooperating agencies including the SHPO and Bureau of Reclamation. As with the other case study, the preconstruction steps in the cultural resource clearance process were completed without problem. The pipeline right-of-way was inventoried, resulting in the identification of 218 cultural resource sites (Express Pipeline 1995a). The 218 sites were evaluated as to their eligibility for the NRHP. Many of the sites required test excavations to determine whether buried, intact cultural remains were present. Based on the evaluations and test excavations, seven of the most significant prehistoric sites were chosen for data recovery excavations (Fig. 6). Additionally, effects to a historically significant trail which is crossed at several places by the pipeline route were also mitigated by means of HABS recording, special construction techniques at the trail crossing, and production of a historic overview for the trail. The crossing of the trail consisted of narrowing the right-of-way, matting over the trail, and not placing spoil piles on the trail.

A Treatment Plan was prepared, proposing data recovery excavations at the seven sites and mitigation of the effects to the historic trail (Express Pipeline 1995b). The Treatment Plan contained a research design to guide the investigations, methods to be used during the excavations and analyses, a schedule, and site-specific treatment proposals. Each of the seven sites was excavated prior to construction pursuant to the Treatment Plan. The excavations continued from November 1995 to July 1996. To ensure that the investigations were completed before the start of construction, the excavations were conducted throughout the cold and windy Wyoming winter using a tent shelter with heaters and lights (Fig. 7). Though creating some difficult logistics, the shelter allowed the archaeological crew to work throughout the winter in fairly comfortable conditions with only few days lost due to inclement weather.

The results of the excavations will provide considerable information concerning the prehistoric use of the Big Horn and Wind River basins and the highlands separating the two basins. Most of the excavated sites appear to be residential base camps utilized within the last 2,000 years. The sites contained the remains of generalized domestic activities including preparation and cooking for immediate consumption of meat from a wide range of animals, maintenance and manufacture of flaked stone tools, and other processing activities. One of the sites (Site 48FR3356) contained the remains of a large, deep cylindrical basin with oxidized sides. Over 100 kg of heat-altered rock was recovered from the basin. This large basin probably served as an oven to bake roots. Another site, the Carlson site, also yielded two large cylindrical basins that were probably used to bake roots. Site 48NA1425 had the remains of a fairly recent (possibly protohistoric) camp with over 500 ceramic sherds, arrow points, and ochre. Ceramic sherds are fairly rare in Wyoming, as are campsites


Fig. 7. Data recovery excavations being completed under a tent shelter during the cold and windy Wyoming winter.

dating to this fairly recent period. Site 48HO656, located in the mountains between the Big Horn and Wind River basins, produced extensive remains including many types of projectile points representing numerous occupations probably dating over the last 5,000 years. The analysis of the recovered remains is now in progress.

The Treatment Plan for the project also included a Construction Monitoring and Unanticipated Discoveries Plan. The plan required an archaeological inspection of the graded right-of-way and trench after trenching had been completed. The archaeologist would not monitor the actual construction in progress, but would follow along after the trenching and prior to pipe placement and backfilling. Except in the case that human remains were encountered, construction would not be halted due to archaeological discoveries. The Treatment Plan stipulated that block excavations totalling up to 300 $m^2$ in area be excavated after construction if significant finds were made during the trench inspection. Discoveries would be considered significant and eligible for the NRHP if they were judged to have the potential to yield relevant data not already collected during the preconstruction data recovery investigations including sites in different locations or of different ages. Sites judged not to have the potential to yield data relevant to the research design or which would duplicate data already obtained from the preconstruction data recovery investigations would be considered not significant and not eligible for the NRHP. The plan deferred the excavations until after the completion of construction so construction would not be delayed due to unanticipated discoveries, and put a cap on the total amount of area that would be excavated after construction.

The archaeological trench inspection for the project was completed during September, October, and November 1996. The trench was inspected by archaeologists walking along both sides of the trench and examining the trench walls from the ground surface. For safety reasons, the archaeologists did not get into the trench. The archaeologists completed the inspection during the time interval between the trenching and stringing the pipe so that they would not interfere with construction operations. When cultural remains such as artifacts, features, stained occupations layers, heat-altered rock, and concentrations of animal bone were found in the trench or on the surface of the graded construction right-of-way, the archaeologists recorded the finds as a site on site forms and plotted their locations on construction work plans. If the remains were in an area previously recorded as a site, they were included as part of that site. Often, a 2×12 plank laid across two step ladders placed in the trench was used to facilitate recording of remains found within the trench walls. To ensure that the remains could be relocated following construction and reclamation, wooden stakes sprayed with orange paint were placed outside of, and on both sides of, the graded right-of-way in line with the discovery and perpendicular to the trench. The distance from the stakes to the recorded remains was recorded. The archaeological inspectors maintained a daily log and recorded areas inspected, the nature of the areas inspected, any cultural remains identified during inspection, the subsequent treatment of the those remains, and any relevant communications.

During the archaeological inspection, 38 new prehistoric sites were recorded and additional cultural remains were noted at 15 previously documented sites (Express Pipeline 1997a). The 53 localities included a wide variety of remains such as housepits, large cylindrical basins, extensive layers of occupational debris, and other feature types found both in the trench and on the surface of the graded right-of-way (Fig. 8). These remains appear to date to a wide range of time periods, and many represent types not investigated during the preconstruction excavations. The inspection of the trench resulted in the discovery of a variety of remains that were often older and more deeply buried than the kinds found during inventory and testing prior to construction. Eighteen of the sites discovered during the trench inspection were tested after final grading and recontouring to assess their significance. Data recovery excavations will be conducted on the best sites during the 1997 field season (Express Pipeline 1997b).

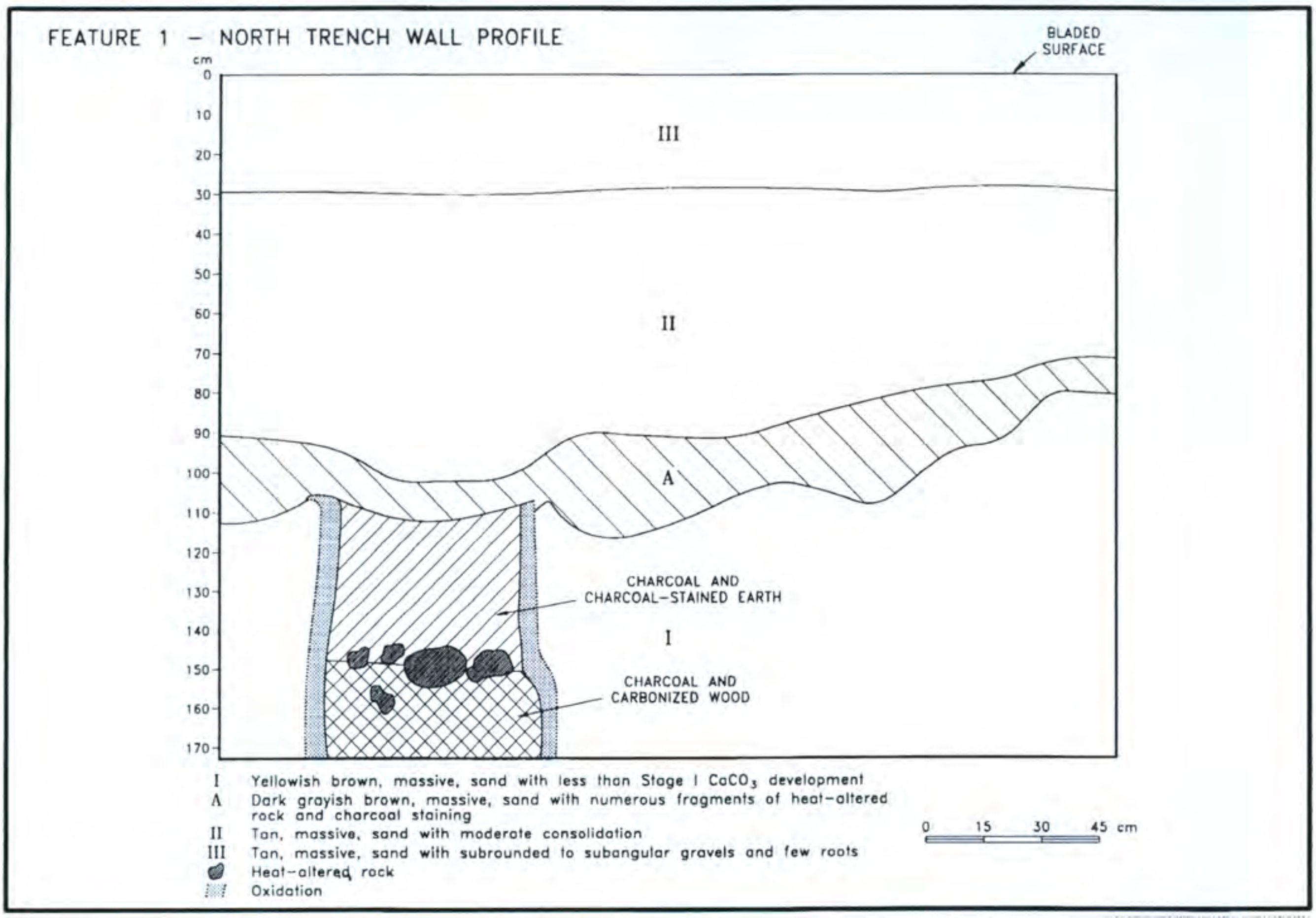



Fig. 8. Example of the kinds of remains found in the pipeline trench during the archaeological trench inspection.

This approach for handling unanticipated discoveries proved quite successful for the pipeline company, and at the same time provided a wealth of archaeological information that would not have been available using other approaches. Even though highly significant remains were encountered during the pipeline construction, construction was never delayed or stopped due to these discoveries. Unanticipated archaeological discoveries were never a factor influencing the pipeline construction schedule. If more traditional methods for unanticipated discoveries had been followed, construction activities would have been stopped numerous times for the many significant remains found on the graded right-of-way and in the trench. Many of the encountered remains would have required extensive data recovery excavations, and if the Case Study One is any indication, the excavations would have to have been completed prior to the resumption of construction in many cases. Many skips in the construction would have been necessary, increasing the cost of construction considerably and possibly delaying the schedule for putting the pipeline into service. Additionally, a more extensive level of effort in the data recovery excavations of the discoveries would have been required than what will be completed during the post-construction investigations. Postponing the data recovery excavations until after the completion of construction allows time for planning and selecting only the most important remains to be excavated. Rushing to complete investigations while construction is being delayed often reduces efficiencies and creates a climate where more extensive work is completed than would otherwise be necessary.

For the archaeology, the trench inspection proved to be an effective means for discovery of deeply buried sites and other site types that would not have normally been found under standard archaeological inventory and testing methods. The trench served as an excellent 330 km cross section across much of Wyoming which facilitated the examination of deposits generally not exposed in other situations. Under this approach that stipulated a pre-established level of post-construction excavation, the most significant of these newly discovered remains will be excavated. These excavations will provide an opportunity to investigate different kinds of sites and remains not encountered during the preconstruction investigations. The post-construction excavations in conjunction with those completed prior to construction allows for a more complete picture of the prehistory of the region that would not have been possible using the more traditional approaches.

## CONCLUSION

These two case studies show how important the consideration of unanticipated cultural resource discoveries during construction is to project planning for pipeline construction. The methods to be employed need to be carefully considered prior to construction and then clearly stated in an Unanticipated Discovery Plan. These discoveries can be handled in many different ways, but a procedure needs to be determined which will be most advantageous for both the pipeline company and the archaeology. In many cases, an approach that allows for construction to proceed without delays while postponing investigations of any archaeological discoveries until after the completion of construction may be in everyone's best interests and should be considered as an effective and efficient alternative.

## REFERENCES

Express Pipeline. 1995a. Inventory and evaluation report, Express Pipeline project, Wyoming segment. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Express Pipeline, Calgary, Alberta.

Express Pipeline. 1995b. Historic properties treatment plan, Express Pipeline project, Wyoming segment. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Express Pipeline, Calgary, Alberta.

Express Pipeline. 1997a. Interim report, trench and right-of-way inspection, Express Pipeline, Wyoming segment. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Express Pipeline, Calgary, Alberta.

Express Pipeline. 1997b. Supplemental historic properties treatment plan for postconstruction data recovery excavations, Express Pipeline, Wyoming segment. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Express Pipeline, Calgary, Alberta.

Foster Wheeler. 1995. Cultural resources mitigation plan and procedures, Northwest Pipeline Corporation Expansion II project, Wyoming facilities. Report prepared by Foster Wheeler Environmental Corporation for Northwest Pipeline Corporation, Salt Lake City, Utah.

McNees, L.M., W.M. Harding, B.R. McClelland, J.D. Marmor, D.W. Newton, B.A. Barrows, S.P. Powley, J.A. Lowe, and C.S. Smith. 1993. Phase 1 cultural resources investigations for the Northwest Pipeline System Expansion II project, Muddy Creek North and Kemmerer North Loops, Lincoln County, Wyoming. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Ebasco Environmental Corporation and Northwest Pipeline Corporation.

McNees, L.M., B.R. McClelland, J.A. Lowe, J.D. Marmor, E. Schneider, and C.S. Smith. 1994. Phase 2 cultural resources investigations for the Northwest Pipeline System Expansion II project, Muddy Creek North and Kemmerer North Loops, Lincoln County, Wyoming. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Enserch Environmental Corporation and Northwest Pipeline Corporation.

McNees, L.M., E.A. Schneider, B.R. McClelland, W.M. Harding, J.A. Lowe, and C.S. Smith. 1996. The archaeology of the Weston site on the upper Bear River, Lincoln County, Wyoming. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Foster Wheeler Environmental Corporation and Northwest Pipeline Corporation.

McNees, L.M. and C.S. Smith. 1995. Treatment plan, Site 48LN3117, Northwest Pipeline Corporation System Expansion II project, Kemmerer North Loop, Lincoln County, Wyoming. Report prepared by TRC Mariah Associates Inc., Laramie, Wyoming, for Foster Wheeler Environmental Corporation and Northwest Pipeline Corporation.

## *BIOGRAPHICAL SKETCH*

***Craig S. Smith***
*TRC Mariah Associates Inc., 605 Skyline Dr., Laramie, WY 82070, USA*

Craig Smith is cultural resource program manager for TRC Mariah Associates Inc., an environmental consulting firm. Over the past 23 years, Mr. Smith has managed cultural resource projects for the pipeline and electrical transmission industries. He has developed many innovative time- and money-saving approaches to cultural resource work. He has a M.A. degree in anthropology from Washington State University.

# Part VI
# Wildlife

# Effects of the Introduction of a Pipeline Right-of-Way with Planted Travel Corridors to a Deer Wintering Area in Northern New York

**Kevin R. Dominske**

In 1991, a buried natural gas pipeline was installed through a deer wintering area located in northern New York State. Five conifer travel corridors were installed across the right-of-way in 1993 to promote deer crossings. A research plan was developed to determine the effects of the introduction of the 20-m right-of-way into the deer yard. The study was designed to determine the effects of the pipeline right-of-way on browse availability and deer movements throughout the yard. The deer wintering area was evaluated for browse availability prior to construction in 1991, and again in 1993 after pipeline construction and right-of-way restoration were completed. Track count surveys were performed prior to construction in 1991, and post-construction and restoration in 1993 and 1994 to determine effects on deer movements. The results of the surveys indicated the introduction of the right-of-way did not have a demonstrable short-term impact on browse availability or deer movements throughout the yard. Planted travel corridors appear to have had a beneficial effect on the willingness of deer to cross the right-of-way.

*Keywords*: White-tailed deer, Odocoileus virginianus, wintering area, yard, right-of-way, browse, travel corridor, New York, Lewis County

## INTRODUCTION

### Project background

The Iroquois Gas Transmission System (IGTS, Iroquois) is a 375-mile buried natural gas pipeline located in the states of New York and Connecticut. The pipeline traverses from the United States–Canadian border at the St. Lawrence River, through upstate New York and western Connecticut, and across Long Island Sound, to Long Island. The pipeline was installed in 1991, and restoration of the right-of-way was generally completed in 1992.

A research plan was developed prior to installation of the pipeline to study the impacts of the introduction of a right-of-way to white-tailed deer (*Odocoileus virginianus*) wintering areas, or yards. The right-of-way width through the deer wintering area selected for this study was limited to approximately 20 m. Five conifer travel corridors were installed across the right-of-way in this yard in 1993, to promote deer crossings.

The importance of coniferous shelter in the winter energy balance of white-tailed deer was described in detail by Verme (1965). Taylor (1956) described the propensity of deer to concentrate in restricted portions of their range during winter months. In addition, the importance of small forest openings to improve browse for white-tailed deer is also well documented (McCaffery and Creed 1969). The degree of interspersion of cover with browse producing areas is as important as the extent of cover area itself (Gill 1957). Construction of a cleared pipeline right-of-way (i.e., within which trees are cut and vegetation is subsequently maintained as predominantly low-growing herbaceous species) through a winter yard thus has the potential to affect the value of coniferous shelter in the vicinity of the right-of-way, and the availability of browse in and adjacent to the right-of-way.

Electric transmission line corridors can be an important source of year-round deer browse (Potvin 1972; Goodwin 1975; Cavanaugh et al. 1976; Eaton and Gates 1979; Potvin and Huot 1979; Bramble and Byrnes 1981; Cerratini 1987). Lunseth (1987) found that the presence of a pipeline right-of-way increased vegetation diversity in areas that were previously unproductive for ungulates. Additionally, browse production was higher on a 17-year old right-of-way and forest ecotone than in a two-year old right-of-way and adjacent undisturbed forest. Garant and Doucet (1995) found that winter cuts for vegetation maintenance on electric transmission line rights-of-way in Quebec substantially increased the availability of winter browse.

Several researchers have examined the effect of energy transmission rights-of-way on deer habitat and movements in deer winter yards. Based on track surveys, Doucet et al. (1979) found that a 30-m wide electric transmission line right-of-way located in a winter yard in Quebec was utilized significantly less by deer than adjacent forested areas. The right-of-way, which succeeded from primarily herbaceous to shrub-dominated vegetation during the five-year study, represented loss of winter habitat but did not act as a barrier to deer movements (Doucet et al. 1979).

The presence of a 500 kV electric transmission line right-of-way was found to seasonally restrict ungulate movements in Idaho (Goodwin 1975). Jackson and Hecklau (1995) investigated the effects of 345 kV electric transmission line rights-of-way varying from 45 to 90 m in width on deer movements in New York deer yards. Track and trail analyses over six winters showed significant differences in use between on and off right-of-way areas, however further study is needed to determine the right-of-way width(s) where crossing is precluded or significantly reduced (Jackson and Hecklau 1995). The installation of planted travel corridors or maintenance of natural travel lanes across rights-of-way has generally been found to promote deer crossings, both in Vermont (Willey and Marion 1980) and Quebec (Lamothe and Dupuy 1984).

The majority of past studies have investigated the effects of electric transmission line rights-of-way on deer movements and browse availability. These corridors generally tend to be wider than those associated with buried pipelines, such as the 20-m wide IGTS right-of-way. No information was found in the literature regarding the response of deer movements and habitat (browse availability) to a narrow pipeline right-of-way with planted travel corridors.

### Study objectives

The primary objectives of this study are to: (1) Determine if the introduction of a pipeline right-of-way through a deer wintering area changes availability of browse within the right-of-way as compared to adjacent forested areas; and (2) Determine the effects of the pipeline right-of-way and planted travel corridors on deer movements within a winter yard.

A deer wintering area located within Jadwin Memorial Forest in the northern New York Town of Diana in Lewis County was selected for this study, based primarily on pre-construction field surveys of the proposed right-of-way. The Jadwin deer yard is an unmapped extension of a state-designated deer wintering area located east of the pipeline route, and had the highest level of winter deer activity of those areas investigated prior to construction of the pipeline.

## STUDY AREA

### Site location

The site selected for this study is located in a deer wintering area traversed by the pipeline in northern New York State, in the Jadwin Memorial State Forest. Specifically, the deer yard is located in the Town of Diana, Lewis County. This deer wintering area had not been identified by the New York State Department of Environmental Conservation (DEC) prior to pipeline construction, but is an unmapped extension of a DEC-designated deer wintering area located east of the pipeline route. The Jadwin yard was identified during pre-construction field surveys of the proposed right-of-way in November 1990, and was subsequently verified during field surveys performed in January and February 1991.

The overall length of the crossing of the Jadwin yard is approximately 3,000 m (Davies 1991). This includes a 700-m "core" area of heaviest use, and approximately 2,300 m of "fringe" winter habitat, which is generally used to a lesser degree. The yard is bordered by State Highway 812 to the west, and open hardwood forest to the east. The total area of the yard encompasses over 600 acres.

### Site description

The Jadwin deer wintering area consists primarily of upland coniferous and mixed forest, with small areas of shrub and forested wetland along its western edge. The topography is generally flat, with shallow sandy soils and numerous granite bedrock outcrops. The 700-m core area of shelterwood within the yard is dominated by *Pinus strobus*, *Thuja occidentalis*, and *Abies balsamea*. The canopy is generally closed and extends to a height of 20–30 m. Ground cover is sparse, limited primarily to ferns and mosses, and there is a moderate to sparse understory of *P. strobus*, *T. occidentalis*, *Acer rubrum*, and *Tsuga canadensis*.

The remaining 2,300-m fringe portion of the yard is dominated by *P. strobus*, *A. rubrum*, *Betula alleghaniensis*, and *T. canadensis*. Forest structure is similar to that found in the core area, however there is generally less winter cover available in the understory. This is due primarily to the replacement of *T. occidentalis* with hardwood species in the fringe understory.

The few wetland areas along the western edge of the deer yard consist primarily of *A. rubrum*, *Betula populifolia*, and *Alnus rugosa*. These areas are interspersed with shallow to deep pockets of standing water which expand and deepen to the west of the study area. These deep open water areas are spring-fed and effectively preclude deer movements to the west even in winter, since they generally do not freeze solidly.

## METHODOLOGY

### Browse density surveys

A total of five transects aligned parallel to the right-of-way were established in the Jadwin study area. The center transect was established along the pipeline centerline, with the remaining four located at 10 m and 60 m respectively from either side of the right-of-way. A total of 21 stations were established along each of the five transects, at 30-m intervals, to correspond to the area of highest winter use within the yard. Transects and stations were established in 1991 and marked with colored flagging. These same transects and stations were used throughout the study period to provide a consistent means of locating data collection points.

Densities of browse plants (stems/$m^2$) along these transects were determined using plot sampling. The number of stems 0.4–2.5 m high and less than 3 cm in diameter were counted on 4 $m^2$ circular plots. A total of 50 randomly located plots were evaluated on each transect. Browsed and unbrowsed stems were recorded as separate categories.

Browse density surveys were performed in 1991 prior to pipeline construction, and again in 1993 after construction and restoration of the right-of-way had been completed. The browse survey was designed to determine whether the anticipated loss of woody browse within the right-of-way following pipeline installation would result in a significant decrease in browse availability as compared to off right-of-way areas within the yard, rather than to provide a comparison among years, so that natural fluctuations in browse production from year to year did not influence the results. A chi-square ($\chi^2$) "goodness of fit" test was used to determine whether there was a statistically significant difference in browse availability between transects in a given year, both prior to construction and after restoration was completed, at a 95% confidence level.

### Track count surveys

Track count surveys were conducted using the same transects and stations established for the browse density surveys. Track surveys were performed within 72 hours of a snowfall of 15 cm or more so that new tracks could be distinguished from old ones (Doucet et al. 1979). Each transect was walked for its entire length, and the location, number, and direction of each track or set of tracks crossing the right-of-way was recorded. Measurements of snow depth to ground and to crust, the location of deer bed sites, and the location of any other evidence of heavy deer use were noted for reference in data analysis.

Track surveys were performed in the winter of 1990–91 prior to pipeline construction, and again in the winters of 1992–93 and 1993–94, after right-of-way restoration was largely completed. In the spring of 1993, two rows of closely spaced 1.8 m (6-ft) tall *Picea glauca* trees were planted across the right-of-way in six locations within the Jadwin deer yard, in order to provide travel corridors for deer movements across the right-of-way. Consequently, the 1994 track survey was the only one conducted with planted travel corridors present on the right-of-way.

The number of crossings along each transect in any given year of the survey was compared using a chi-square ($\chi^2$) "goodness of fit" test to determine whether there was any difference in use between right-of-way, edge, and interior transects at a 95% confidence level. No comparisons were made between years so that natural fluctuations in deer use of the yard resulting from factors such as severity of winter weather did not influence the results.

## RESULTS

### Browse density surveys

Browse density surveys were conducted prior to construction of the pipeline in the spring of 1991, and again in the fall of 1993 after construction and restoration were largely completed. Results were tabulated as the number of browsed and unbrowsed stems per square meter on each transect. Table 1 summarizes the results of the browse density surveys. Both the total number of stems (browsed + unbrowsed), and the number of browsed stems only, were evaluated to determine potential differences in browse availability among the transects.

A chi-square analysis of the 1991 pre-construction browse data indicates there is no statistically significant difference in browse availability among the transects surveyed at a 95% confidence level. Although transect C (centerline) showed higher levels of browse availability than the other transects, these were determined not to be statistically significant, both when counting browsed stems only ($\chi^2$ = 0.41, 2 d.f., $P < 0.05$), and when including browsed and unbrowsed stems ($\chi^2$ = 5.7, 2 d.f., $P < 0.05$).

An analysis of the 1993 post-construction browse data also indicates there is no statistically significant difference in browse availability among the transects. Because the post-construction browse survey was conducted only two years after installation of the pipeline, virtually no woody browse had yet reestablished on the right-of-way centerline transect (C) at the time of survey. This lack of woody browse on the right-of-way,

**Table 1. Summary of browse density survey results**

| Survey year | Number of stems/$m^2$ (browsed/unbrowsed) | | | | |
|---|---|---|---|---|---|
| | A* | B | C | D | E |
| 1991 | 1.9/4.7 | 1.8/2.8 | 3.0/10.9 | N/A | N/A |
| 1993 | 1.0/0.4 | 1.4/0.6 | 0/0 | 1.7/0.7 | 1.7/0.7 |

*A–E denote transect designations.
Source: Phenix Environmental, Inc. 1996.

however, was not sufficient to cause a statistically significant difference in browse availability among the transects overall, either when counting browsed stems only ($\chi^2$ = 1.7, 4 d.f., $P < 0.05$), or when including both browsed and unbrowsed stems ($\chi^2$ = 2.5, 4 d.f., $P < 0.05$).

In summary, there was no statistically significant difference in browse availability indicated among the transects, either in 1991 or 1993, at the 95% confidence level.

### Track count surveys

Table 2 presents the mean snow depths, both to crust and to ground, recorded during the three track surveys. Snow depths to ground were higher in 1993 and 1994 than in the pre-construction survey, however depth to crust was similar in 1991 and 1994. The mean depth to crust in 1993 was greater than in either the 1991 or 1994 survey.

Track count data were collected as the number of crossings on each transect. The track count survey results for all three years are summarized in Table 3.

An analysis of the 1991 pre-construction track count data shows that there are statistically differences in use among the transects ($\chi^2$ = 30.8, 4 d.f., $P < 0.05$). The centerline (C) and eastern edge (D) transects were used most heavily, while the westernmost transects (A and B) were used to a lesser degree. The heaviest use on all five transects occurred toward the southern end of the deer yard.

A chi-square analysis of the 1993 track count survey results also shows a statistically significant difference in use among the transects ($\chi^2$ = 16.8, 4 d.f., $P < 0.05$). In 1993, the centerline transect (C) was used less than any of the edge or interior transects. It should be noted that 1993 also had the deepest snow depths to crust of any survey year, and travel corridor plantings had not yet been installed.

**Table 2. Mean snow depths along transects in survey years 1991, 1993, and 1994**

| Survey year | Snow depth to crust/to ground (cm) | | | | |
|---|---|---|---|---|---|
| | A* | B | C | D | E |
| 1991 | 18/23 | 22/25 | 17/19 | 22/25 | 14/17 |
| 1993 | 50/75 | 55/76 | 43/77 | 47/72 | 46/66 |
| 1994 | 20/76 | 15/60 | 15/73 | 28/63 | 25/75 |

*A–E denote transect designations.
Source: Phenix Environmental, Inc. 1996.

**Table 3. Summary of track count survey results**

| Survey year | Number of crossings | | | | |
|---|---|---|---|---|---|
| | A* | B | C | D | E |
| 1991 | 24 | 18 | 55 | 52 | 31 |
| 1993 | 57 | 45 | 26 | 63 | 53 |
| 1994 | 23 | 13 | 28 | 14 | 18 |

*A–E denote transect designations.
Source: Phenix Environmental, Inc. 1996.

An analysis of the 1994 track count survey data shows no statistically significant difference in use among the transects ($\chi^2$ = 8.3, 4 d.f., $P < 0.05$). The centerline transect (C) was used slightly more than the edge or interior zone transects (A, B, D, E), however the differences in use were not statistically significant at the 95% confidence level. Planted travel corridors had been installed on the right-of-way prior to the collection of 1994 data, however there were no crossings recorded in the immediate vicinity of any of the plantings. In addition, although not protected by fencing or similar measures, no browsing of the planted trees within the travel corridors was observed. Consequently, although deer use of the right-of-way increased in 1994 following the installation of the corridors, there was no direct evidence of their use by deer, and thus their beneficial effect is somewhat speculative.

In summary, there was a statistically significant difference in use among the transects at a 95% confidence level both in 1991 and 1993; however, there was no significant difference in use indicated by the 1994 data.

## DISCUSSION

### Browse density surveys

Based on analyses of 1991 and 1993 browse data, there was no significant difference in browse availability among the transects in either year. Introduction of a right-of-way into the deer yard did result in a decrease in woody browse available on the cleared right-of-way, but this was not sufficient to result in a statistically significant difference in browse availability overall within the yard.

These findings are somewhat in contrast to a number of previous studies which have found that rights-of-way can be an important source of winter browse (Potvin 1972; Goodwin 1975; Cavanaugh et al. 1976; Eaton and Gates 1979; Potvin and Huot 1979; Bramble and Byrnes 1981; Cerratini 1987; Garant and Doucet 1995). The lack of woody browse on the right-of-way in this study is largely due to the short duration of the study following pipeline installation (two years), which did not permit sufficient time for woody species to become reestablished. Over time, the availability of browse on the right-of-way will likely increase to some degree as woody species recolonize cleared areas. Portions of the temporary construction right-of-way will be allowed to revert entirely to natural woody vegetation, and the permanent 15-m right-of-way will be maintained by mechanical mowing only once every 5–7 years, allowing some colonization of the permanent right-of-way by woody species in the interim. For example, Lunseth (1987) found that browse production on a 17-year old pipeline right-of-way was significantly greater than on one only two years old.

Differences in maintenance techniques between transmission line and pipeline rights-of-way will minimize the degree to which woody browse reestablishes on the IGTS right-of-way in future years, and thus will likely contribute to future differences in browse availability on the pipeline right-of-way relative to the electric transmission line corridors examined in previous studies. Electric transmission line rights-of-way are generally maintained in a state of low-growing woody vegetation (i.e., small trees and shrubs), while the 15-m permanent Iroquois pipeline right-of-way will be maintained in primarily herbaceous vegetation over the life of the pipeline. Consequently, it can be expected that browse availability will be somewhat less than in similar electric transmission line corridors over the life of the pipeline.

As a result of clearing of the right-of-way and subsequent revegetation with grasses and legumes, there was a shift from woody browse to herbaceous forage within the right-of-way. As noted above, this loss of woody browse did not result in a statistically significant difference in woody browse availability among the transects throughout the yard; however, it does represent the loss of a small amount of woody browse within the permanent right-of-way. This change from woody browse to herbaceous forage may in fact represent an overall improvement in habitat diversity, as there is generally little to no herbaceous forage available in off right-of-way transects at any time throughout the year. Lunseth (1987) also found that the presence of a pipeline right-of-way increased vegetation diversity.

Herbaceous forage is generally not available in the winter months due to deep snow cover, so the value of any increased habitat diversity is likely minimized at this time of year. However, scrapings where deer were apparently attempting to reach herbaceous forage through the snow cover on the right-of-way were fairly common during the 1993 survey, and even more so in 1994. In addition, several springs were evident on the right-of-way following pipeline construction through the deer yard. Snow depths around these springs were generally much less than in adjacent areas, and deer use of these springs was fairly heavy. Scrapings around these springs where there was little snow cover were also fairly common. Consequently, although introduction of the right-of-way represented a small loss of woody browse, this may well be offset by an increased availability of water and herbaceous forage on the right-of-way.

### Track count surveys

Analyses of track count data indicate a statistically significant difference in use among the transects in 1991 and 1993, but not in 1994. Use of the right-of-way transect was low in 1993, but high in 1991 and 1994. In 1994, the right-of-way was actually used more heavily than any of the edge or interior transects. Travel corridors had been planted on the right-of-way prior to the 1994 survey, so these may have been a factor in use of the right-of-way by deer. However, no crossings were recorded on the right-of-way in the immediate vicinity of the planted travel corridors, so their value in providing access points for deer to cross the right-of-way has not been established. Willey and Marion (1980) and Lamothe and Dupuy (1984) also found that planted travel corridors generally tend to promote deer crossings of rights-of-way.

The lack of travel corridors in 1993 may have been a factor in the low use of the right-of-way by deer in that year, however the high snow depth to crust in 1993 was likely the most significant factor. The depth to crust was 43 cm in 1993, but only 15 cm in the 1994 survey. Deep snow impedes deer mobility, thus discouraging crossings of the right-of-way and restricting deer to the edge and interior zones, where there is greater cover. The deep snows in 1993 also tended to cover many of the springs which were exposed in 1994. This may also have been a factor in low deer use of the right-of-way in 1993. The local deer population becoming accustomed to the presence of the right-of-way over the length of the study may also have been a factor in greater use of the right-of-way in 1994.

Notes made on the presence of deer beds along each of the transects indicate that the introduction of the right-of-way did not discourage bedding along its edges. There were numerous beds noted along the edge transects (B and D) both in 1993 and 1994. Consequently, it can be assumed that the 10-m separation of the edge transects from the right-of-way was a sufficient distance to provide deer adequate cover for bedding.

In summary, the presence of the 20-m pipeline right-of-way in the Jadwin deer yard did not discourage deer use or crossings of the right-of-way area in 1994. This is in contrast to a number of previous studies which found deer use and movements in winter yards to be restricted in electric transmission line rights-of-way (Goodwin 1975; Doucet et al. 1979; Jackson and Hecklau 1995). However, the existing literature does not pinpoint the specific width which precludes or significantly restricts winter use of a right-of-way. The rights-of-way examined in previous studies were significantly wider (ranging from 30 to over 90 m) than the 20-m Iroquois right-of-way. Consequently, the narrower width was likely a factor in its greater use than those examined in previous studies. The presence of planted travel corridors may also be a contributing factor to the greater use of the 20-m right-of-way.

## CONCLUSIONS

### Browse density surveys

The introduction of the 20-m wide IGTS right-of-way into the Jadwin deer yard did not result in a significant difference in browse availability among the various transects established in the yard. There was a small loss of woody browse within the right-of-way proper, however the loss was insufficient to cause a statistically significant difference in browse availability among the transects at the 95% confidence level.

### Track count surveys

The introduction of the 20-m Iroquois right-of-way did result in significant differences in use among the transects in 1993, but by 1994 there were no differences in use apparent. Potential factors contributing to differences in use in 1993 include high snow depths, lack of travel corridors, and deer being unaccustomed to the presence of the right-of-way. Conversely, potential factors in these differences being eliminated by 1994 include lesser snow depths (and thus greater availability of water and herbaceous forage on the right-of-way), the presence of travel corridors, and deer becoming accustomed to the presence of the right-of-way.

Based on the 1994 data, the introduction of the 20-m wide right-of-way did not result in significant changes in deer movement patterns through the yard, and did not discourage deer from crossing the right-of-way and making full utilization of the entire wintering area. Since 1994 is the only year of survey where there were planted travel corridors present on the right-of-way, they likely had a beneficial effect on the willingness of deer to cross the right-of-way. However, this cannot be firmly established since there was no evidence of deer using these corridors directly to cross the right-of-way.

## ACKNOWLEDGMENTS

I would like to thank the Iroquois Pipeline Operating Company as sponsors of this project, the New York State Department of Environmental Conservation for permitting the collection of field data on lands under their stewardship, and my fellow Phenix staffers who assisted with the collection of data and preparation and review of this report.

## REFERENCES

Bramble, W.C. and W.R. Byrnes. 1981. Effect of an electric transmission right-of-way on forest wildlife habitat. In: Proceedings of the Second Annual Symposium on Environmental Concerns in Rights-of-way Management. EPRI WS-78-141.

Cavanaugh, J.B., D.P. Olson, and S.N. Macrigeanis. 1976. Wildlife use and management of power line rights-of-way in New Hampshire. In: Proceedings of the First National Symposium on Environmental Concerns in Rights-of-way Management. Mississippi State University, Mississippi.

Cerratini, D.G. 1987. Influence of white-tailed deer on electric transmission line right-of-way vegetation. Northeastern Environmental Science, 6(1): 37–45.

Davies, B. 1991. Personal communication. New York State Department of Environmental Conservation Forester. Jadwin Memorial State Forest, Dadville, New York.

Doucet, G.J., R.W. Stewart, and K.A. Morrison. 1979. The effect of a utility right-of-way on white-tailed deer in a northern deer yard. In: Proceedings of the Second Annual Symposium on Environmental Concerns in Rights-of-way Management. EPRI WS-78-141.

Eaton, R.H. and J.E. Gates. 1979. Transmission rights-of-way management and white-tailed deer habitat: a review. In: Proceedings of the Second Annual Symposium on Environmental Concerns in Rights-of-way Management. EPRI WS-78-141.

Garant, Y. and G.J. Doucet. 1995. An experimental winter cut in a powerline ROW located in a white-tailed deer yard. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-way Management. Montreal, Quebec, Canada.

Gill, J.D. 1957. Review of deer yard management 1956. Game Division Bulletin 5. Maine Department of Inland Fish and Game. Augusta, Maine.

Goodwin, J.G. 1975. Big game movement near a 500 kV transmission line in northern Idaho. Bonneville Power Administration Technical Report. Portland, Oregon.

Jackson, L.W. and J. Hecklau. 1995. Construction effects of a 345 kV electric corridor on New York deer. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-way Management. Montreal, Quebec, Canada.

Lamothe, P. and P. Dupuy. 1984. Special consideration for implanting two 735 kV lines in the Hill Head Deer Yard near Montreal. In: Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-way Management. San Diego, California.

Lunseth, B.G. 1987. Browse production and utilization on a pipeline right-of-way. In: Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-way Management. Indianapolis, Indiana.

McCaffery, K.R. and W.A. Creed. 1969. Significance of forest openings to deer in northern Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 44. Madison, Wisconsin.

Potvin, F. 1972. L'amenagement integre de la faune et de la foret du Quebec. Normes generales. Ministere du Tourisme, de la Chasse et de la Peche, Faune Quebec Bulletin No. 16. Montreal, Quebec, Canada.

Potvin, F. and J. Huot. 1979. Deer browse production in small cutovers in southern Quebec. Wildlife Society Bulletin, 7(4): 247–252.

Taylor, W.P. 1956. The deer of North America. The Stackpole Company. Harrisburg, Pennsylvania.

Verme, L.J. 1965. Swamp conifer deer yards in northern Michigan: Their ecology and management. Forestry, 63: 523–529.

Wiley, C.H. and L.F. Marion. 1980. Transmission line corridor crossings for white-tailed deer. In: Transactions of the Northeast Wildlife Conference No. 37. pp. 90–103.

## *BIOGRAPHICAL SKETCH*

***Kevin R. Dominske***

*Phenix Environmental, Inc., P.O. Box 613, Boonville, NY 13309-0613, USA*

Kevin R. Dominske is a wildlife biologist currently in the employ of Phenix Environmental, Inc. in Boonville, New York. He has been a professional in the environmental field since graduating from the State University of New York College of Environmental Science and Forestry in 1988, working primarily in the fields of fish and wildlife biology and wetland delineation.

# Effects of Clear-Cutting and Debris Removal on Ruffed Grouse Activity in an Experimental Right-of-Way

G. Jean Doucet, Ross MacCulloch, and J. Roger Bider

Logging operation clear-cuts and utility rights-of-way are plentiful in many parts of ruffed grouse (*Bonasa umbellus*) range. The effects of such clearings on regional populations could be important in grouse management. Limited information is available concerning effects of the original clear-cutting of a right-of-way on ruffed grouse. The objective of this experiment was to determine the effect of the original clear-cutting and debris removal in a 20 m wide experimental right-of-way on the activity and habitat utilization of ruffed grouse. Grouse activity was recorded using the sand transect technique. Data collected before (1971, 1972) and after (1973, 1974) the clearing were used to determine the change in grouse activity in cleared versus forested areas. In 1973, no grouse activity was recorded in the study area. In 1974, summer grouse activity was much higher in the experimental right-of-way compared to the control area. It is difficult to determine if food or cover was responsible for the increase in activity recorded in the cleared area in 1974.

*Keywords*: Activity, *Bonasa umbellus*, clear-cut, right-of-way, ruffed grouse, sand transect

## INTRODUCTION

The effects of vegetation disturbance on ruffed grouse (*Bonasa umbellus*) abundance and habitat utilization have been discussed by several authors. Rusch and Keith (1971) reported that ruffed grouse fed on willows (*Salix* spp.) in a recently burned area during winter in Alberta. Small openings in forested areas are important for ruffed grouse activity (Bump et al. 1947, Sharp 1963, Berner and Gyzel 1969, Gullion 1972). Schemnitz and Byrnes (1963) observed greater counts of ruffed grouse in older rights-of-way treated with herbicides while Bramble and Byrnes (1982) observed feeding by ruffed grouse on pioneer vegetation in established rights-of-way in Pennsylvania. Hollifield and Dimmick (1995) estimated the biomass of arthropods available to ruffed grouse in old logging roads. In general, ruffed grouse appears to be adapted to habitats in early stages of successional development.

Restoration of earlier successional stages in mature forests can be a tool in grouse habitat management. Clear-cuts from logging operations or utility rights-of-way are plentiful throughout most of ruffed grouse range and their effects on regional populations and habitat utilization could be important in ruffed grouse management. The effects of large clearings have been studied, but limited information exists concerning the effects of original clear-cutting of rights-of-way on ruffed grouse. The objective of this study was to determine the effect of original clear-cutting and debris removal from an experimental right-of-way on activity and habitat utilization of ruffed grouse.

## STUDY AREA

The field work was carried out during four consecutive summers (1971–1974) at the Lac Carré ecological station, 110 km northwest of Montreal, Quebec (46°09′ N, 74°29′ W). The study area included two habitats: (1) an old field, approximately 10 ha, last pastured in 1953 and planted with 20–40 cm balsam firs (*Abies balsamea*) in 1962, and (2) an adjacent stand of mixed forest. Succession in the old field was advanced and vegetation was characterized by willows, trembling aspen (*Populus tremuloides*), wild red cherry (*Prunus pensylvanica*), balsam fir and white birch (*Betula papyrifera*). Goldenrods (*Solidago* spp.) were the most common tall

**Table 1. Total numbers of ruffed grouse crossings over the sand transects in the summers 1971–1974**

| Year | Sampling dates | Control transect (140 m) no. of crossings | Treatment transect (75 m) no. of crossings | Ratio control/ treatment |
|---|---|---|---|---|
| 1971 | 04 July–30 Sept. | 129 (0.92) | 171 (2.28) | 1/2.47 |
| 1972 | 14 June–23 Aug. | 40 (0.29) | 55 (0.73) | 1/2.52 |
| 1973 | 17 Aug.–16 Sept. | 0 (0.00) | 0 (0.00) | – |
| 1974 | 30 June–08 Aug. | 28 (0.20) | 212 (2.83) | 1/14.15 |

() Numbers in brackets indicate the number of crossings/m of transect.

herbs. Except for poplars and willows, few trees reached 3 m in height in the old field section. The mixed forest was characterized by poplars, balsam firs and maples (*Acer* spp.) which often reached 25 m in height. The understory consisted of wild red cherry, choke-cherry (*Prunus virginiana*), white birch and hazelnut (*Corylus cornuta*). The ground vegetation included club moss (*Lycopodium* spp.), bracken (*Pteridium aquilinum*), blueberries (*Vaccinium* spp.) and bush honeysuckle (*Diervilla lonicera*) along with short and tall herbs. Bider (1968) and Wishart and Bider (1976) have described the vegetation in detail.

## METHODS

Grouse activity was recorded using the sand transect technique (Bider 1968). Tracks were read at least four times a day and total daily activity was recorded as the number of grouse crossings over a 140 m long control transect and a 75 m treatment transect. The two transects were located 250 m apart and consisted of 50 cm wide strips of fine sand laid out under a 1.7 m wide and 2 m high polyethylene canopy to protect the transect fine sand from rain. The use of uneven lengths of transects to obtain data on grouse for this experiment is due to the fact that we used sand transects laid out in the area for multiple studies on animal communities and not specifically for the experiment reported in the present paper. Since results are compared in terms of ratio for given lengths of transect, the uneven transect lengths have no bearing on the results. Transects were read al least four times each day and the total daily numbers are tabulated to give the annual total. Data were recorded continuously for entire sampling periods, however, a few days had to be excluded from the data set due to transect washouts by rain.

The treatment area was clear-cut between 22 August and 31 August 1972. Unlike conventional logging where most trees are felled and slash is left on the ground, trees and shrubs in the experimental right-of-way were cut manually with chain saws and hand tools. Great care was taken to spare the transect. Trees, branches and debris from the cutting were removed from the treatment (clear-cut) area. The treatment transect remained operational and was read along with the control transect during the cut and slash removal operation. The linear forest opening created a 20 m wide experimental right-of-way. Data collected before (1971, 1972) and after (1973, 1974) the clearing are used to determine the change in grouse activity in the cleared versus forested areas.

## RESULTS AND DISCUSSION

Grouse activity is reported as annual totals for each year and as the number of crossings of grouse per meter of transect for the entire summer sampling periods (Table 1). The number of crossings/m of control transect were 0.92 and 0.29 for 1971 and 1972 respectively. The number of crossings/m of treatment transect were 2.28 and 0.73 for 1971 and 1972 respectively. These data yield similar control/treatment ratios of 1/2.47 for 1971 and 1/2.52 for 1972, before cutting (Table 1).

In the first summer after the clear-cut (1973), the transects were read for one month. No grouse crossings were recorded during that period (Table 1). Obviously no grouse were in the study area at that time. Bergerud (1988) considers predation to be a major mortality factor for grouse. We can only speculate that local population changes, poor spring survival or predation could be responsible for these 1973 results.

In 1974, 28 grouse crossings were recorded on the control (uncut) transect while 212 crossings were recorded on the treatment transect (Table 1). This represents an activity rate of 0.20 crossings/m of transect on the control and 2.83/m on the treatment. The 1/14.15 ratio was more than a five-fold increase from the 1/2.5 recorded before (1971 and 1972) the clear-cut and clearly indicated that summer grouse activity was much higher in the experimental right-of-way two years after the clear-cut.

Openings less than half a hectare in deciduous forest are important for broods (Sharp 1963) and ground vegetation can serve as food and cover against predators and inclement weather. Schemnitz and Byrnes (1963) and Bramble and Byrnes (1982) observed ruffed grouse activity in well established rights-of-way, while Bevanger (1993) reported high willow ptarmigan (*Lagopus lagopus*) in powerline rights-of-way in Norway.

Availability of food and ground cover are the two major reasons why ruffed grouse would use cleared areas. In forest openings, food availability is often increased (Seastedt and Crossley 1981). The clearing in our study supported great amounts of aspen and willow coppice, blueberries, raspberries (*Rubus* spp.), goldenrods and other species. Ground insect activity increased significantly in the treatment area in 1974 (Doucet and Bider 1984) and insects can be important food for young grouse (Bump et al. 1947). In addition, the thick vegetation stratum of the first meter above ground offered grouse and especially broods excellent cover from predators and direct sunlight.

In 1974, at the treatment transect, most of the activity (68%) occurred before 9:00 a.m. while the remainder of activity occurred in the afternoon and early evening. It is possible that grouse were taking advantage of the abundant insect food source (Doucet and Bider 1984). Hollifield and Dimmick (1995) observed high invertebrate populations in old logging roads in the Appalachians. Ruffed grouse were also very active in these old roads (Hollifield and Dimmick 1995). However, it remains difficult to determine if food or cover was responsible for the increase in activity recorded in the cleared area in 1974. Possibly, the two factors were complementing each other in providing favorable grouse habitat.

## CONCLUSION

Data presented show that grouse were more active in a cleared experimental right-of-way than in the adjacent forest two years after the clear-cut. However, it is difficult to identify the causal factors. The micro-habitat at ground level was greatly modified by the clear-cut and possibly the interaction of cover and food were responsible for the increased grouse activity recorded. We postulate that recently cleared rights-of-way produce favorable summer habitat for ruffed grouse in northeastern forests. However studies are needed on a larger scale to address questions related to: cover, food (including invertebrates), drumming sites and predation in assessing the quality of rights-of-way as ruffed grouse habitat.

## REFERENCES


Bergerud, A.T. 1988. Population ecology of North American grouse. In: Adaptive Strategies and Population Ecology of Northern Grouse. Volume II. Theory and Synthesis. University of Minnesota Press, Minneapolis, Minnesota. pp. 578–685.

Berner, A. and L.W. Gyzel. 1969. Habitat analysis and management considerations for ruffed grouse for a multiple use area in Michigan. Journal of Wildlife Management, 33: 769–778.

Bevanger, K. 1993. Hunting mortality versus wire-strike mortality of willow grouse *Lagopus pagopus* in an upland area of southern Norway. In: Proceedings for Avian Interactions with Utility Structures — International Workshop. EPRI TR-103268. pp. 11:1–10.

Bider, J.R. 1968. Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Ecological Monographs, 38: 269–308.

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 Agriculture Experiment Station Research Bulletin 974. 24 pp.

Bump, G., R.W. Darrow, F.C. Edminster, and W.R. Crissey. 1947. The ruffed grouse: life history, propagation, management. New York State Conservation Department. 915 pp.

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 of the Third International Symposium on Environmental Concerns in Rights-of-Way Management, San Diego, California. pp. 592–601.

Hollifield, B.K. and R.W. Dimmick. 1995. Arthropod abundance relative to forest management practices benefiting ruffed grouse in the southern Appalachians. Wildlife Society Bulletin, 23(4): 756–764.

Rusch, D.H. and L.B. Keith. 1971. Ruffed grouse-vegetation relationships in central Alberta. Journal of Wildlife Management, 35: 417–429.

Schemnitz, S.D. and W.R. Byrnes. 1963. Wildlife utilize line rights-of-way. Science for the Farmer, 10: 3.

Seastedt, T.R. and D.A. Crossley, Jr. 1981. Microarthropod response following cable logging and clear-cutting in the southern Appalachians. Ecology, 62: 126–135.

Sharp, W.M. 1963. The effects of habitat manipulation and forest succession on ruffed grouse. Journal of Wildlife Management, 27: 664–671.

Wishart, R.A. and J.R. Bider. 1976. Habitat preference of woodcock in southwestern Quebec. Journal of Wildlife Management, 49: 523–531.


## *BIOGRAPHICAL SKETCHES*


***G. Jean Doucet***

*Direction Communication et Environnement, Hydro-Québec, 75 René-Lévesque, W., Montréal, Québec, Canada H2Z 1A4*


Jean Doucet holds a Ph.D. in wildlife biology from McGill University and has been a member of the environmental research unit at Hydro-Québec for ten years. He is currently managing a research program on mammals and birds in relation to hydroelectric energy production and transmission. Studies on large ungulates and biodiversity in relation to rights-of-way are major aspects of this research program.


***Ross MacCulloch***

*Royal Ontario Museum, Toronto, Ontario, Canada*


Ross MacCulloch holds an M.Sc. in wildlife biology from McGill University. His main research interests are in the field of amphibian and reptile ecology. He is presently assistant curator of reptiles and amphibians at the Royal Ontario Museum, Toronto, Ontario.

*J. Roger Bider*
*St-Lawrence Valley Natural History Society, Ste-Anne-de-Bellevue, Québec, Canada*

Roger Bider holds a Ph.D. in wildlife biology from Université de Montréal and has been studying vertebrate populations for thirty years. He is presently Director of the St. Lawrence Valley Natural History Society Ecomuseum. His present research interests are focused on threatened populations of amphibians and reptiles.

# Snowshoe Hare, Red Squirrel and Gray Squirrel Winter Activity in a 120 kV Powerline Right-of-Way and in Adjacent Forests

G. Jean Doucet and David T. Brown

Snowshoe hare (*Lepus americanus*), red squirrel (*Tamiasciurus hudsonicus)* and gray squirrel (*Sciurus carolinensis*) activity was monitored during two winters in a 30 m wide 120 kV powerline right-of-way on Rigaud mountain in Vaudreuil County, Quebec. Track counts in the snow indicated that hares were significantly more active in the adjacent forest than in the right-of-way itself. During the first winter of the study, there was no vegetation emerging from the snow and there were no complete crossings of the right-of-way by hares. All observed hare trails entering the right-of-way returned to the side they came from without crossing. During the second winter, the vegetation in the right-of-way was thicker and hares began crossing the right-of-way. By the end of January of the second winter, no hare trails were recorded in either the forest on one side of the right-of-way or in the right-of-way itself. Hares continued to create trails on the other side of the right-of-way until early February when hare activity ceased throughout the general area. These observations could be the results of indirect factors such as disease or predation being more intense on one side of the right-of-way or being impeded in moving from one side to the other. Red squirrels and gray squirrels crossed the right-of-way throughout the 1981-82 winter but the activity was significantly higher in the adjacent forest than in the right-of-way. These results underline the need for studies on habitat fragmentation and small mammals related to utility rights-of-way.

*Keywords*: Habitat fragmentation, right-of-way, snowshoe hare, squirrels, 120 kV

## INTRODUCTION

In the past, wildlife concerns in right-of-way routing were mainly focused on habitat loss and many routing studies only considered game species (Doucet et al. 1984). More recently rights-of-way studies have included habitat fragmentation issues (Piepers and Bekker 1995, Kamstra et al. 1995, Mousseau et al. 1995). However, there are still very limited data on the effects of a powerline right-of-way on animal communities (Bramwell and Bider 1981, Ladino and Gates 1981, Doucet and Bider 1984). The objective of this paper is to present data on the fragmentation of snowshoe hare (*Lepus americanus*), red squirrel (*Tamiasciurus hudsonicus*) and gray squirrel (*Sciurus carolinensis*) habitat by powerline rights-of-way.

## STUDY AREA

Data were collected during the winters of 1980–81 and 1981–82 in the Rigaud deer yard located approximately 60 km west of Montreal, in Vaudreuil County, Quebec (45°26'N, 74°20'W). The powerline right-of-way where the experiment was conducted was 30 m wide and contained a twin-pole 120 kV transmission line built in 1972 (Fig. 1). The forest habitat near the right-of-way was characterized by deciduous or mixed stands interspersed with small islands of hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*). Other species included hawthorn (*Crataegus* spp.), sumac (*Rhus typhina*), red-osier dogwood (*Cornus stolonifera*), trembling aspen (*Populus tremuloides*), eastern cottonwood (*Populus deltoides*), balsam poplar (*Populus balsamifera*),

Fig. 1. The study area.

American elm (*Ulmus americana*), ashes (*Fraxinus* spp.), choke-cherry (*Prunus virginiana*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*) and willows (*Salix* spp.). The right-of-way also bisected a stand of mature white cedars (*Thuja occidentalis*). During the fall 1980, the entire right-of-way was mechanically cut and treated with a herbicide. The following summer (1981) more than 150 plant species were observed in the right-of-way, including trembling aspen, eastern cottonwood, balsam poplar, willows, red-osier dogwood, sumac, ash and various tall and short herbs. The first winter (1980–81) of the study was unusual with little snow accumulation on the ground. However, during the winter of 1981–82 the snow accumulation on the ground exceeded 50 cm for 40 consecutive days. During that period (mid-winter 1982), very few plants were tall enough to emerge through the snow.

## METHODS

These data on hare and sciurids were collected while monitoring winter activity of deer on linear transects. Data were collected by observers walking a 1.22 km right-of-way segment running between a concession road (St-Henri Rd.) and agricultural lands. Surveys were done three to five days after a snowfall that covered all existing tracks. Habitat utilization was determined by tabulating the number of snowshoe hare, red squirrel and gray squirrel trails crossing four parallel transects oriented along the same axis as the 30 m wide right-of-way. Two transects were located within the right-of-way, each being approximately 6 m from the outer edges of the clear-cut area. The other two transects were located in the uncut forest 30 m outside the edge of the clear-cut area. Snowshoe hare tracks were recorded during two winters (1980–81, 1981–82) while squirrel tracks were recorded during a single winter (1981–82). Since snow conditions (ex. drift, melt) make it practically impossible to distinguish red squirrel tracks from those of gray squirrels with certainty, sciurid data were pooled.

## RESULTS AND DISCUSSION

During the winter of 1980–81, very little snowshoe hare activity was recorded in the right-of-way while up to 52 trails crossed the 1.22 km survey transect in the wooded area (Table 1). During the first winter, there was no vegetation emerging from the snow and at no point did hares cross the entire right-of-way. Any hares entering the right-of-way returned to the woods from the same side they entered. Snow cover was greatly reduced by the end of January in the first winter and hare trails could no longer be followed. December 1981 surveys conducted during the second winter, indicated more hare activity in the forest on each side of the right-of-way, but also several crossings of the entire right-of-way were observed (Table 1). Snow depth was greater during the second winter but some vegetation was showing through, especially early in the winter. Snow depth in the right-of-way during February and March 1982 was between 45 and 60 cm.

A major change in hare activity patterns was recorded in late January 1982 when 56 hare trails were recorded in the forest on one side of the right-of-way while no activity was recorded on the other three transects (Table 1). No hare tracks were observed in the general area after the first of February 1982 and during the rest of the winter. It is difficult to determine what triggered this crash in hare activity on only one side of the right-of-way. However, the notable difference suggests that newly cleared powerline rights-of-way represent a barrier to hare movements, affecting activity patterns and isolating local wildlife populations over the course of a given winter. Hare could be in competition with white-tailed deer (*Odocoileus virginianus*) for the available food in the right-of-way (Brown and Doucet 1991). For example, both species were observed to feed on red-osier dogwood in the right-of-way during the winter. However, we do not believe that interspecific competition could have caused the observed population crash. A more likely explanation is an outbreak of a communicable

**Table 1. Number of tracks and trails of snowshoe hare observed in the right-of-way and adjacent forest during the winters of 1980–82**

| Date | Forest West | ROW West | ROW East | Forest East |
|---|---|---|---|---|
| 05/12/80 | 37 | 0 | 0 | 32 |
| 30/12/80 | 29 | 0 | 1 | 11 |
| 15/01/81 | 20 | 0 | 6 | 52 |
| Total 80–81 | 86 | 0 | 7 | 95 |
| 14/12/81 | 47 | 2 | 9 | 31 |
| 31/12/81 | 96 | 25 | 11 | 35 |
| 27/01/82 | 56 | 0 | 0 | 0 |
| Total 81–82 | 199 | 27 | 20 | 66 |

**Table 2. Number of tracks and trails of red and gray squirrels observed in the right-of-way and adjacent forest during the winter of 1981–82**

| Date | Forest West | ROW West | ROW East | Forest East |
|---|---|---|---|---|
| 14/12/81 | 27 | 5 | 10 | 56 |
| 31/12/81 | 6 | 4 | 0 | 13 |
| 27/01/82 | 3 | 2 | 3 | 15 |
| Total 81–82 | 36 | 11 | 13 | 84 |

disease (e. g. tularemia) that was delayed in crossing the right-of-way due to limited hare movement.

As expected, red squirrels and gray squirrels were more active in the adjacent forest than in the right-of-way (Table 2). Although some sciurid trails crossed the right-of-way, most animals did not cross and returned to the side where they came from. These data again suggest that a denuded right-of-way may represent a barrier to red squirrel and gray squirrel movements in winter. Oxley et al. (1974) observed reduced small mammal activity across roads.

## CONCLUSION

Lower snowshoe hare and sciurid activity levels were observed in the right-of-way than in the adjacent forest. Also, few hare and squirrel trails crossed the right-of-way from one forest stand to the other. These observations suggest that rights-of-way may cause at least temporary habitat fragmentation in winter, especially during winters immediately following vegetation control in the right-of-way.

The winter data on snowshoe hare, red squirrel and gray squirrel indicate that, although movements were impeded, small mammals can cross a 30 m wide powerline right-of-way during that season. Activity across the right-of-way was higher when some vegetation was showing through the snow in the right-of-way during the second winter. We would expect that the activity level would increase as more vegetation appears in subsequent winters, particularly to the degree that resprouting shrubs become a desirable winter food source for hares.

The unusual pattern in hare activity the second winter indicates that something happened in the forest on one side of the right-of-way (activity crash) several weeks before it took place on the other side of the right-of-way. Whether these data indicate fragmentation in relation to processes such as predation, disease, or man-induced mortality remains unanswered. No evidence of trapping or hunting was observed in the general area where the transects were located. Ongoing monitoring of small mammal movements is needed to confirm whether such movements become less restricted as the right-of-way revegetates following vegetation control. The data presented, albeit based on short surveys, underline the need to document the role of rights-of-way in habitat fragmentation and animal communities.

## REFERENCES


Bramwell, R.N. and J.R. Bider. 1981. A method for monitoring the terrestrial animal community of a powerline right-of-way. In: Proceedings of the Second Symposium on Environmental Concerns in Rights-of-Way Management. EPRI WS-78-141, 45: 1–17.

Brown, T.D. and G.J. Doucet. 1991. Temporal changes in winter diet selection by white-tailed deer in a northern deer yard. Journal of Wildlife Management, 55(3): 361–376.

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 of the Third Symposium on Environmental Concerns in Right-of-Way Management. San Diego, California. pp. 592–601.

Doucet, G.J., J.R. Bider, P. Lamothe, and D.T. Brown. 1984. Wildlife data issues in the routing of energy corridors. In: Proceedings Symposium on Facility Siting and Routing: Energy and Environment, 2: 491–506.

Kamstra, J., S. Hounsell, and W. Weller. 1995. Vulnerability of reptiles and amphibians to transmission corridors and facilities. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 300–304.

Mousseau, P., M. Giguère, and G.J. Doucet. 1995. Analyse de différentes causes d'abandon de la héronnière de Watopeka traversée par la ligne à 450 kV Radisson/Nicolet/Des Cantons. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 308–311.

Ladino, A.G. and J.E. Gates. 1981. Response of animals to transmission-line corridor management practices. In: Proceedings of the Second Symposium on Environmental Concerns in Rights-of-Way Management. EPRI WS-78-141, 53: 110.

Oxley, I.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology, 11(1): 51–59.

Piepers, A. and H. Bekker 1995. Mitigating habitat fragmentation due to road infrastructure in the Netherlands. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec. pp. 319–322.


## *BIOGRAPHICAL SKETCHES*


***G. Jean Doucet***

*Direction Communication et Environnement, Hydro-Québec, 75 René-Lévesque, W., Montréal, Québec, Canada H2Z 1A4*


Jean Doucet holds a Ph.D. in wildlife biology from McGill University and has been a member of the environmental research unit at Hydro-Québec for ten years. He is currently managing a research program on mammals and birds in relation to hydroelectric energy production and transmission. Studies on large ungulates and biodiversity in relation to rights-of-way are major aspects of this research program.

*David T. Brown*

*Environmental Policy Institute, Brock University, St. Catharines, Ontario, Canada L2S 3A1*

David Brown holds a Ph.D. in wildlife biology from McGill University. He is former Director of the Environmental Policy Institute at Brock University, where he has been active in work on linear corridors and greenways. He is currently on sabbatical leave at Burapha University, Chonburi, Thailand, working on integrated sustainable waste management.

# White-Tailed Deer (*Odocoileus virginianus*) Use of Forested Travel Corridors in a Twin 735 kV Powerline Right-of-Way — 20 Years of Observations

**G. Jean Doucet and Yves Garant**

To avoid long detours in routing the first corridor of the James Bay high voltage transmission network, the 150 m wide right-of-way was routed through the Hill Head and La Macaza white-tailed deer (*Odocoileus virginianus*) winter yards. Bisecting deer yards with such a wide right-of-way raised questions about post-construction deer movement in these yards; especially across the right-of-way movement. The issue was resolved by leaving forested travel lanes for deer in the right-of-way. These lanes were located at sites where, over the years, deer had established networks of trails and runways in the forest. Tower heights were increased from 50 to 75 m in order to obtain allowable conductor/tree clearance at Hill Head. Deer winter activity pattern was monitored before (1978) and after (1979–1980) construction. Deer used the travel lanes during the first winter. Various aerial and pellet group surveys conducted between 1986 and 1994 indicate that deer are still using these forested travel lanes, more than 17 years after construction. It is our opinion that under certain circumstances, travel lanes could be successful to address specific habitat fragmentation concerns.

*Keywords*: Activity, deer yard, forested travel lane, habitat fragmentation, powerline, Quebec, right-of-way, white-tailed deer, winter, 735 kV

## INTRODUCTION

Over the past 20 years, the routing of powerline rights-of-way through white-tailed deer (*Odocoileus virginianus*) winter yards has triggered heated debates concerning the possible impacts of rights-of-way on these protected habitats in Quebec. When a right-of-way is selected to cross a deer yard, utility biologists consider various mitigation measures, such as winter clearing, mechanical rather than chemical vegetation control and conservation of forested travel lanes within the right-of-way. The first two are aimed at improving browsing conditions, while the forested corridors are meant to protect existing cover. The efficiency of such measures are rarely followed for more than a few years.

In the mid 1970s, to avoid long detours in routing the first corridor of the James Bay high voltage 735 kV transmission network, the 150 m wide right-of-way (twin lines) was routed through the Hill Head and La Macaza white-tailed deer winter yards in southern Quebec. This raised great concerns about habitat fragmentation in relation to post-construction winter deer movement in these yards; especially across the right-of-way movement. The issue was addressed by leaving forested travel lanes for deer in the right-of-way. These lanes were located at sites where networks of deer trails and runways were already established over the years in the forest. Deer winter activity in those forested lanes was monitored before (1978) and after (1979–1980 and 1986–1994) construction.

The 150 m wide right-of-way was cleared in February–April 1979 and six forested vegetation travel lanes were left in the right-of-way in two different deer yards (four in Hill Head, and two in La Macaza). To achieve required conductor/tree clearance, towers were raised 25 m in the Hill Head deer yard (Lamothe and Dupuy 1984). Locating towers on high points achieved the required conductor/tree clearance in the La Macaza yard.

The objective of this paper is to report on the fate and deer use of forested travel corridors left in a 150 m wide powerline right-of-way to facilitate deer movement across the right-of-way in yards during winter. The data address both the life of the mitigation measure and deer activity in these corridors over the years.

## STUDY AREA

The Hill Head (49 km$^2$) and La Macaza (160 km$^2$) deer yards are located respectively 40 km and 120 km northwest of Montreal (Quebec). The Hill Head yard presents a southern exposure with rolling topography and has harbored approximately 500 deer over the years. Mixed stands of sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), Canada hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and white spruce (*Picea glauca*) are the dominant cover types in the Hill Head yard. Four forested travel lanes were left in the Hill Head right-of-way, including two, lanes A and B, in the core of the yard (Figs. 1 and 2).

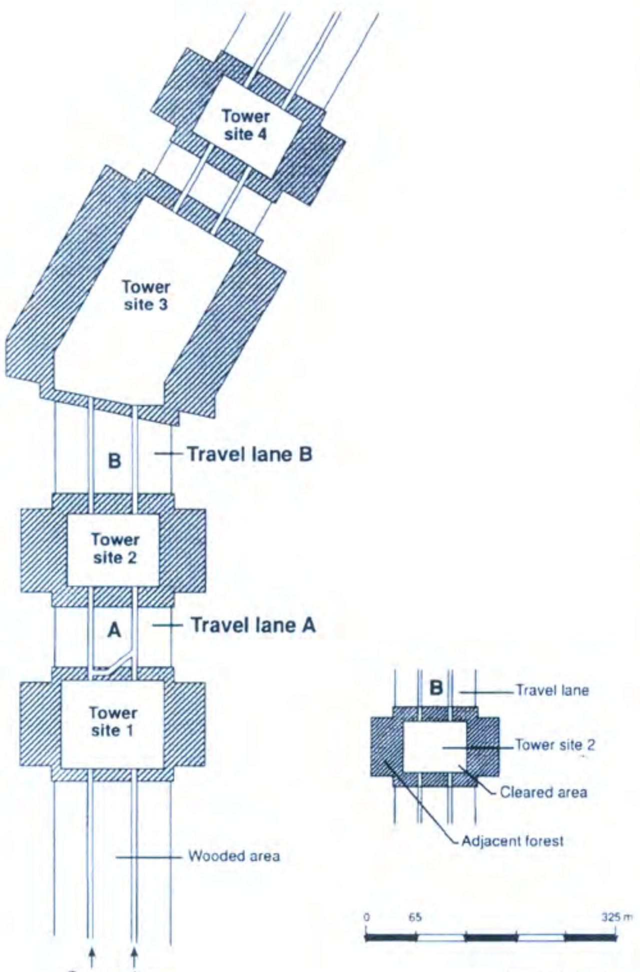



Fig. 1. Schematic view of forested travel lanes in the Hill Head deer yard.

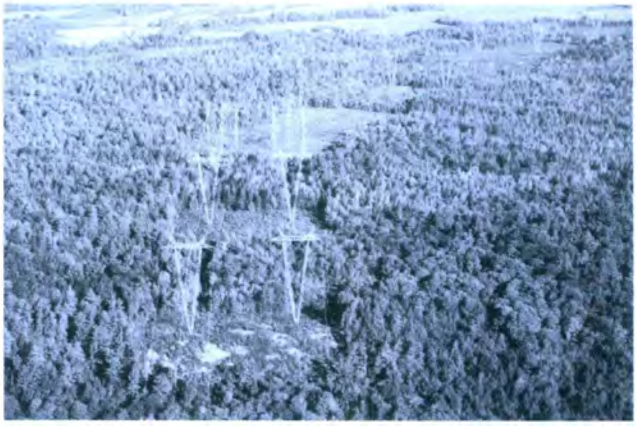


Fig. 2. Forested travel lanes in the Hill Head deer yard.

Fig. 3. Forested travel lane in the La Macaza deer yard.

The La Macaza deer yard is located at the northernmost limit of the white-tailed deer range in Quebec. In the vicinity of the powerline right-of-way, the yard habitat is dominated by deciduous species such as trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*) and large-toothed aspen (*Populus grandidentata*), interspersed with coniferous species such as balsam fir (*Abies balsamea*), white spruce and Eastern white cedar (*Thuja occidentalis*). At construction time, two forested travel lanes were left in the right-of-way (Fig. 3). In recent years, the La Macaza yard has sheltered a winter population of 3000 to 4000 deer.

Both yards are bisected by a twin 735 kV powerline right-of-way from the James Bay network. The right-of-way is 150 m wide and is oriented in a north-south direction in both yards. It crosses the Hill Head yard over a distance of 3 km while it runs for 10 km through the La Macaza yard.

## METHODS

The Hill Head deer yard was surveyed more often than La Macaza because it was part of a monitoring network for 10 years and it was more accessible than the La Macaza yard. Observations of deer activity in the Hill Head yard were collected before (1978) and after (1979–1980) the construction of the powerline right-of-way. Various aerial surveys were conducted between 1986 and 1995 to collect qualitative data on deer use in the right-of-way and travel lanes. Quantitative data on deer activity were obtained by pellet group surveys conducted in 1978, 1981 and from 1986 to 1992. For example, two travel lanes in the Hill Head yard were surveyed eight times for pellet groups over a 12 year period (1981–1992). Pellet-groups were tallied in 20–30 sample plots (2×40 m) randomly distributed in travel lanes A and B (Fig. 2) located within the limits of the yard; at least half of the pellets had to be in the plot to be counted (Potvin 1978). We used a daily defecation rate of 13 pellet groups/day (Potvin 1978) to convert pellet groups/ha into deer-days/ha.

Although casual observations were recorded on several occasions, travel lanes located in the right-of-way of the La Macaza deer yard were not surveyed systematically over the years. However, four aerial surveys were conducted; one in March 1993 and three during the 1994 winter (January–March). Deer tracks and runways in the right-of-way were tallied during each survey. No quantitative analysis of deer activity (pellet-group survey) was conducted in this yard.

## RESULTS

Forested travel lanes left in the Hill Head and La Macaza deer yards are still in place and relatively intact after 20 years. In general, most forested travel lanes left in rights-of-way in Quebec deer yards have resisted windfall and have maintained the same forest vegetation characteristics that were present when the rights-of-way were cleared.

Deer used the forested travel lanes to cross the Hill Head right-of-way during the winter of the clear-cut (during and after the clearing of the right-of-way). Runways located where lanes were maintained remained active after construction (BELT 1981). Casual observations during helicopter flights indicated that deer continued to use forested travel lanes to cross the right-of-way in subsequent winters. Results from pellet group surveys also indicated (Fig. 4) that deer spent a lot of time in those two travel lanes in winter. Heavy deer use of travel lanes in the La Macaza right-of-way was observed during helicopter overflights in wintertime (e.g., Doucet and Bouchard 1995). One forested lane, located at the crossing of the Rouge river (Fig. 3), was intensively used according to the deer trail patterns observed near that site.

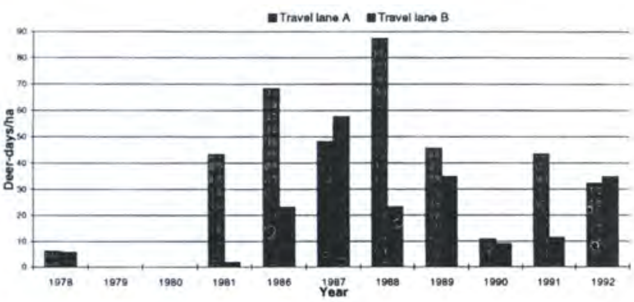



Fig. 4. Deer activity in the travel lanes in the Hill Head deer yard, based on pellet group counts.

## DISCUSSION

During the past 10 years, Hydro-Quebec conducted more than 100 winter overflights in rights-of-way located in deer yards. Deer can easily move across narrow rights-of-way (30–60 m wide) in winter (Doucet et al. 1987). In all permanent yards visited, deer tracks and trails were always observed crossing open sections of rights-of-way, even in more than 1 m of snow, indicating that powerline rights-of-way do not represent an absolute barrier to deer movement in winter. However, during deep snow conditions deer activity was mainly limited to major runways in the rights-of-way.

Although not a necessity for crossing rights-of-way, forested travel lanes are used by deer in winter. Forested lanes left in conifer or mixed stands were generally traveled more than those in deciduous stands indicating that cover is the main factor that affects deer activity level in forested corridors. Dasmann (1971), Halls (1984) and Ozoga (1995) have presented extensive reviews on the importance of winter cover for deer in terms of climate, snow and escape from predation. Other studies have reported deer use of forested travel lanes in winter yards (Willey and Marion 1980, Doucet et al. 1983). Ad hoc aerial and ground observations also indicated that forested travel lanes left in the Watopeka deer yard (450 kV, cleared in 1989) and the Kingsey Falls deer yard (735 kV, cleared in 1987) are used by deer in winter to cross these rights-of-way (Garant 1992). The key practical question is whether forested travel lanes should be mandatory in all rights-of-way in deer yards or used only in specific situations to reduce habitat fragmentation for white-tailed deer in wintertime. We postulate that, in wide rights-of-way (e.g., 735 kV) under deep snow conditions (e.g., valleys), forested travel corridors facilitate deer movement across the right-of-way. As we approach the next millennium, the issue of wildlife habitat fragmentation remains a serious concern (Harris 1984). The results observed in deer yards monitored in the present study indicate that forested lanes in rights-of-way could be used to reduce the fragmentation effect on a local level.

## CONCLUSION

Forested travel lanes appear to be long lasting mitigation measures. Deer started to use forested travel lanes immediately after the clear-cutting of the rights-of-way in winter yards. In Hill Head and La Macaza yards, deer are still using the travel lanes almost 20 years after the original clearing. We can conclude that forested lanes are favorable habitats (not necessarily preferred sites) for deer to cross wide rights-of-way. Based on our observations, we postulate that forested travel lanes could be used to entice deer to cross a right-of-way in the event of habitat fragmentation in a northern yard. However, this remains to be tested in a field situation.

## REFERENCES

BELT. 1981. Étude d'impact de la traversée du ravage de cerfs de Virginie de Hill Head: 1re et 2e lignes à 735 kV du Complexe La Grande. Rapport Synthèse, Direction Environnement, Hydro-Québec. 66 pp.

Dasmann, W. 1971. If Deer Are To Survive. Wildlife Management Institute. Stackpole Books, Harrisburg, Pennsylvania. 128 pp.

Doucet, G.J., D.T. Brown, and P. Lamothe. 1983. White-tailed deer response to conifer plantation as a mitigation measure in a powerline right-of-way located in a Quebec deer yard. In: Proceedings of the 40th Northeast Wildlife Conference, Mount Snow, Vermont, May 28. 40: 150–156.

Doucet, G.J., D.T. Brown, and P. Lamothe. 1987. Deer behavior in a powerline right-of-way located in a northern wintering yard. In: Proceedings of the Fourth Symposium on Environmental Concerns in Rights-of-Way Management. Indianapolis, Indiana. pp: 7–12.

Doucet, G.J. and D. Bouchard. 1995. Couloirs de traversée: emprise traversant le ravage de cerfs de Virginie de La Macaza. Service Milieu naturel, Vice-Présidence Environnement, Hydro-Québec. 10 pp.

Garant, Y. 1992. Les emprises de lignes dans les ravages de cerfs de Virginie. Production de nourriture et utilisation par les cerfs. Ravages de Bedford, Rigaud, Hill Head, Kingsey Falls, Rawdon, lac David, Notre-Dame-du-Laus, Watopeka et lac du Trente-et-Un-Milles. Vice-présidence Environnement, Hydro-Québec. 56 pp.

Halls, L.K. (ed.). 1984. White-tailed Deer: Ecology and Management. Wildlife Management Institute, Stackpole Books, Harrisburg, Pennsylvania. 870 pp.

Harris, L.D. 1984. The Fragmented Forest. The University of Chicago Press, Chicago, Illinois. 211 pp.

Lamothe, P. and P. Dupuy. 1984. Special consideration for implanting two 735 kV lines in the Hill Head deer yard; near Montreal. In: Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management. San Diego, California. pp. 581–591.

Ozoga, J.J. 1995. Whitetail Winter — Seasons of the Whitetail: Book Two. Willow Creek Press, Minocqua, Wisconsin. 159 pp.

Potvin, F. 1978. L'inventaire du brout: Revue des méthodes et description de deux techniques. Ministère Tourisme, Chasse et Pêche, Service de la Faune. Rapport Spécial No. 9. 88 pp.

Willey, C.H. and L.F. Marion. 1980. Transmission line corridor crossings for white-tailed deer. In: Proceedings of the 37th Northeast Wildlife Conference, Ellenville, New York, 30 May. 37: 91–103.

## *BIOGRAPHICAL SKETCHES*

***G. Jean Doucet***

*Hydro-Québec, 75 René-Lévesque, W., Montréal, Québec, Canada H2Z 1A4*

Jean Doucet holds a Ph.D. in wildlife biology from McGill University and has been a member of the environmental research unit at Hydro-Québec for ten years. He is currently managing a research program on mammals and birds in relation to hydroelectric energy production and transmission. Studies on large ungulates and biodiversity in relation to rights-of-way are major aspects of this research program.

***Yves Garant***

*Naturam Environnement, 31 Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*

Yves Garant holds an M.Sc. degree in Renewable Resources from McGill University and has been working as a wildlife consultant since 1986. He has conducted several research projects in rights-of-way management for Hydro-Québec. His main research interests are ungulate and furbearer ecology and management.

# Experimental Storage of Terrestrial Lichen and Implications for Reclamation of Caribou Habitat

**Randal Glaholt, Chris Meloche, and Laura VanHam**

Terrestrial lichen form an important component of winter range for caribou inhabiting mountainous areas in northeastern British Columbia. Species of lichen belonging to the genera *Cetraria*, *Cladina* and *Stereocaulon* are common on these high elevation ranges and are typically found on more xeric sites characterized by unique edaphic conditions and often subject to wind scour and advanced snow melt. The present study was undertaken to experimentally investigate the feasibility of lichen salvage and storage for subsequent use in restoration of lichen communities on alpine caribou range. Lichen were manually collected from an alpine site, air dried indoors for approximately 75 days and then stored under three conditions; (1) outside, exposed to ambient conditions (Calgary, Alberta), (2) inside at room temperature in a ventilated plastic feedsack, and (3) in a freezer at a constant temperature of –15°C. The former storage condition allowed exposure to the regular photo period, the latter two conditions prevented light exposure of the lichen samples. Preliminary experiments investigating enzyme (nitrogenase) activity, respiration and photosynthesis, tissue cell count and growth were performed to examine the viability of stored samples as well as samples collected fresh at the time of experimentation. As expected, initial results indicate that fresh collected samples exhibit the highest viability as measured by the four analysis performed. Although all three storage treatments yield viable samples, room temperature stored samples appear to exhibit the highest viability in all but the nitrogenase activity test.

*Keywords*: Alpine, caribou, *Cetraria*, *Cladina*, lichen, *Rangifer*, reclamation, *Stereocaulon*

## INTRODUCTION

A significant aspect of oil and gas activity within western Canada involves exploration and development within previously undisturbed portions of the Rocky Mountains. Geological characteristics of the area, practical limitations of directional drilling technology, local geography and use of conventional access methods still requires that some well sites, access roads and pipeline rights-of-way be constructed within alpine and high sub-alpine environments.

These same environments are also important to a number of wildlife species which are dependent on these areas for forage and predator avoidance. Among these, certain populations of "woodland" or "mountain" caribou (*Rangifer tarandus caribou*) are closely associated with alpine and high sub-alpine environments and have been recognized as a special conservation concern. Woodland caribou diets in western Canada show specific selection for a high percentage of terrestrial and/or arboreal lichen (Thomas et al. 1996, Russell et al. 1993, Stevenson and Hatler 1985). Studies of caribou diets suggest that in general, the *Rangifer* genus relies heavily on lichen in forage selection (Manseau et al. 1996, Skogland 1980) in particular during the winter season (Thomas et al. 1996, Bloomfield 1979, Wood 1994). During winter, mountain inhabiting woodland caribou tend to utilize alpine and high sub-alpine areas (Wood 1994, Backmeyer 1994, TERA 1996) where certain species of terrestrial lichen are common, particularly those belonging to genera *Cladina* and *Cetraria* (TERA 1996) (see Fig. 1). These foraging sites are typically high elevation (e.g. >1,500 m asl), well drained alpine locations which appear to generally retain less snow cover than surrounding areas.

Vegetation communities within the alpine and high sub-alpine habitats are typically slow to establish and slow growing due to the extreme environmental

Fig. 1. Woodland caribou (*Rangifer tarandus caribou*) on typical alpine winter range in northeast British Columbia.

Fig. 2. Location of alpine caribou winter range to be traversed by exploration road.

conditions which include a very short growing period (Chambers 1995). Lichen are notable in this regard. For example, the growth rate for the rock colonizing, crustose lichen *Rhizocarpon geographicum* ((L.) DC.) has been reported in some alpine and sub-alpine environments to be as slow as 11 mm/century (Vitt et al. 1988). Even at their best, growth rates of lichen can be slow. For example, foliose lichens such as *Peltigera rufescens* ((Weiss) Humb.), which typically grow in dry, exposed environments from montane to the alpine, has been reported to grow at a maximum rate of 27 mm/year (Ahmadjian 1993). Growth rates for the fruticose lichens widely used by caribou, such as *Cladina mitis* ((Sandst.) Hustien) and *C. rangiferina* ((L.) Nyl.), appear to be intermediate with growth rates reported to range from 5.2 mm/year to 7.7 mm/year (Ahmadjian 1993). Depending on the species, individual lichen may exhibit developmental characteristics suggesting growth over periods approaching a thousand years while others may attain full development within a few months to a few years (Honegger 1996). Reproduction in many species of lichen, with their characteristic algal (photobiont) and fungal (mycobiont) symbiotic association, is primarily associated with the asexual production of new propagules (variously classed as soredia and isidia) or by fragmentation of the lichen thallus (body) (Vitt et al. 1988).

Our investigations were undertaken in conjunction with construction of a well site access road in northeastern British Columbia. During the initial route selection for the access road, efforts were made to avoid sensitive habitats including an area identified by biologists as important caribou winter range. The caribou range identified was in a saddle adjoining two higher elevation alpine ridges (see Fig. 2). A large portion of the saddle had an extensive ground cover of terrestrial lichen dominated by *Stereocaulon paschale* with lesser representation by *Cladina mitis*, *C. uncialis* ((L.) Wigg.), *Cetraria nivalis* ((L.) Acn) and *C. cucullata* ((Bell.) Ach.) (classifications performed by Dr. D.H. Vitt). The final route selected involved some encroachment on this lichen rich habitat.

Most lichens are remarkable in their ability to rehydrate and resume normal metabolic functions following periods of desiccation (Nash 1996). In addition, lichens are generally regarded as well adapted to the temperatures experienced in their particular micro habitats (Nash 1996). On a site like Mount Bickford, alpine terrestrial lichens survive cold, low light conditions for several months. Not surprisingly, previous experimentation has shown that air dried lichens in dark storage conditions are quite tolerant of cold stress at both extremely low temperatures (–196°C) (Kappen 1973) and for extremely long periods (proven up to 3.5 years) (Larson 1978). Gradual thawing allows many species to resume normal photosynthetic activity (Nash 1996). These qualities of lichen physiology prompted the undertaken investigation to salvage lichen from the road right-of-way and experimentally store them off-site with the hope that salvaged lichen could be subsequently used as "seed" in future reclamation. Previous research has shown potential for successful reintroduction (or transplant) of species such as *Stereocaulon* and *Cladonia* in mountainous areas (Hutchinson 1969).

The purpose of the research reported here was to evaluate the feasibility of different methods of remote storage of lichen for later use in reclamation. Implications of alternative approaches to the conservation and reclamation of terrestrial lichen communities are discussed.

## METHODS

### Lichen salvage and storage

Lichen were collected within flagged portions of the right-of-way during August 1995 using a shallow toothed garden rake. Salvage was conducted over a one day period under dry conditions. Although precise measurements were not made, collectors observed variable moisture content within the lichen thalli. An effort was made to concentrate collection in areas with a higher percentage of lichen species known to be used by mountain caribou (e.g. *Cladina* spp. and *Cetraria* spp.). Lichen were placed in ventilated, 24-l plastic feed sacks and transported to the long-term storage site by air within 24 hours. Lichen were spread out on a plastic tarp and air dried at approximately 22°C under low light (basement) conditions for approximately 75 days to prevent moist decomposition. Subsamples (>1 kg) were stored from November 1995 to April 1996 (135 days) under the following conditions: (1) outside on a perforated plastic sheet under ambient Calgary conditions of light, humidity and precipitation average total monthly precipitation range from a low of 9.9 mm in February to a high of 25.1 mm in April; average daily temperature range from a low of –9.6°C in January to a high of +4.1°C in April; average relative humidity at 15:00 hours range from a low of 43% in April to a high of 59% in December, Environment Canada, 1993); (2) in the dark in a ventilated, plastic feedsack at room temperature (~22°C); and (3) in the dark in a freezer at approximately –15°C. During the spring of 1996, fresh lichen samples were collected from the same site on 2 April, 21 April and 30 April and delivered for analysis on 4 April, 23 April and 6 May, respectively. Testing lichen for viability under the various treatments was done using enzyme activity analysis, respirometric techniques and cell culturing.

## Nitrogenase activity testing

Lichens such as *Stereocaulon* sp. that contain cyanobacteria such as *Stigonema* sp., *Nostoc* sp. and *Styconema* sp., possess a nitrogenase enzyme system which allows the system to convert or "fix" atmospheric nitrogen into a more useable ammonia form (Hutchinson 1969, Millbank and Kershaw 1973). Such lichen characteristically have a much greater nitrogen content than lichen without cyanobacterial photobionts. Confirmation of nitrogenase enzyme activity in part indicates active lichen metabolism. The test for nitrogenase activity involved use of an acetylene reduction technique slightly modified from that described by Huss-Danell (1977). Subsamples (100 mg) taken from each of the three storage treatments, as well as a fresh sample (100 mg) were re-wetted in 50 ml serum bottles with 200 mg (0.2 ml) distilled water to obtain a moisture content of 200% dry weight. Prior to re-wetting, the frozen subsample was thawed at room temperature. All four subsamples were then prepared for testing as described by Huss-Danell, refrigerated and sent to Norwest Labs of Calgary, Alberta. Acetylene and ethylene assays to measure reduction of acetylene gas to ethylene gas were performed using a Hewlett Packard 5890 model GC.

## Dark respiration and photosynthesis activity testing

Subsamples of *Cetraria nivalis* and *Stereocaulon paschale* were obtained from each of the three storage treatments and from the fresh sample. Prior to testing, dead or discolored fragments of thalli were discarded along with potentially contaminating plant and soil debris in order to minimize the effect of epiphytic microorganism respiration on test results. Though not quantified, there were no obvious differences in the amount of necrotic thallus removed from samples (compared by treatment protocol or species) prior to analytical procedures. We assume, however, that differences recorded in life processes between treatments are likely indicative of the total amount of living tissue per unit of sample.

The cleaned subsamples were submitted to Hydro-Qual Laboratory Ltd., Calgary for respirometric testing, specifically to examine the rate of net oxygen exchange. Lichens were hydrated and incubated under low light conditions for 2–3 days prior to testing. Light incubations were done at 5,000 to 7,500 lux in 1.25 l acrylic containers at 21 ± 2°C (same container, temperature and humidity used for dark incubations). A Hewlett Packard 5700 model GC was used for measurements. Values ($\mu\ 1O_2$/min/g dry wt) were obtained as an average of rate of oxygen exchange following 24-hour and 48-hour incubations for each of the light and dark phase respirations respectively.

Values for the "true" rate of photosynthesis are obtained by correcting the apparent rate of oxygen exchange obtained during the light-phase measurement period by placing the samples in complete darkness (Richardson 1973). Assuming the respiratory rate in the dark is the same as the respiratory rate in the light, the photosynthetic rate (of $O_2$ production) was obtained by subtracting from it the dark respiration ($O_2$ uptake) rate value. The measured rates of gas exchange are a function of the relative amounts of algal and non-algal portions of the lichen thallus used in the experiment (Larson and Kershaw 1975).

## Cell culture testing

Sub-samples of *Stereocaulon paschale* and a 9:1 dry-weight mix of *Cetraria nivalis* and *C. cucullata* were obtained from each treatment. Any fragments of dead or discolored thalli were removed before the test. Approximately 1–5 g dry weight of thallus fragments were selected from each sample and washed with 200 ml phosphate-buffered saline containing Tween 80 (0.01% v/v) as described by Bubrick and Galun A (1986) for 0.5 hours at 200 rpm on a Brunswick Aquatherm shaker/water bath. The washed thalli were then rinsed with cold tap water for one hour on a Buchner funnel and then homogenized in a small blender for one minute with 100 ml sterile distilled water. A modified Yamamoto (1987) Tissue Culture Technique was used. Modifications involved collection of sterile water washed residue and passing this through six successive 20 ml washes with sterile distilled water in 20×125 mm culture tubes and vortexing for three minutes each transfer. Approximately 75–100 thallus fragments of both lichen species were transferred after the final wash to petri dishes containing either Lily and Barnett medium (Ahmadjian 1993) with 1.0 g $NH_4NO_3$ and 1.0 g asparagine or malt extract yeast-extract medium. The sample's thallus fragments were placed on 5 plates of each media type. Plates were incubated at 15±5°C, 875 lux, 16 hour light/8 hour dark photoperiod for 60 days. Microscopic examination (3125×, phase contrast) was used to measure growth of bionts within segments using cellular morphological typing.

### Algal and cyanobacterial isolation test

The homoginized material prepared in the previous test was passed through the 150 µm stainless steel mesh of the Yamamoto tissue culture test and then passed through a pre-sterilized 100 µm nylon filter. The filtrate was collected and serial ten-fold dilutions with sterile water were prepared. Given that the average diameter of *Trebouxia* sp. photobiont vegetative cells is typically 30–40 µm (Ahmadjian 1967), only individual cells or clusters of up to 2 or 3 cells would pass through the filter. The serial dilutions were plated (in three subsamples) onto each of agar solidified, Bold's Basal Medium (BBM), with 1% glucose and for *Stereocaulon* samples only, BBM without nitrogen. The latter media targeted isolation of the cyanobacterial component of *Stereocaulon* which is able to fix atmospheric nitrogen. Petri dish plates were incubated at 15±5°C, 875 lux, 16-hour light photoperiod for 60 days. A 50 ml volume aliquot of the 100 µm screened filtrate was measured and the weight of residue determined by loss in drying at 105°C. Cell counts (CFU/gdw 100 µm filtrate residue) were measured as a standard plate count on the above referenced media.

## RESULTS AND DISCUSSION

### Nitrogen fixing activity

The demonstration of cyanobacterial, nitrogenase enzyme activity, essential for nitrogen fixing in *Stereocaulon paschale*, provides one indication that the stored or otherwise salvaged lichen material was capable of resuming essential life processes. Nitrogenase activity, measured by way of acetylene reduction activity, was detected in all sample but was highest in the "fresh" sample, slightly lower in the "outside" sample and considerably lower in the "room temperature" and "freezer" samples (Table 1). As tests were not performed in replicate, statistical significance of these differences could not be determined. Nitrogen fixation rates are lower in the four assays than for those reported in literature: 110 n mol $C_2 H_2 g^{-1} h^{-1}$ for remoistened *S. paschale* samples collected from northern Sweden in February, 1976 (Huss-Danell 1977). This may be a result of the lower light intensity used in this assay (120 $\mu E\, m^{-2} S^{-1}$ versus 170 $\mu E\, m^{-2} S^{-1}$) and/or physiological, temporal and spatial differences between the two strains of *S. paschale*. As all testing was performed under equivalent conditions of light, temperature and moisture, the reduced nitrogenase activity in the "room temperature" and "freezer" samples was suggestive of cellular or enzymatic damage and/or loss of metabolites that occurred in these samples during their storage or pre-testing preparation.

**Table 1. Nitrogenase activity of *Stereocaulon paschale* subject to different storage conditions utilizing reduction of acetylene gas to ethylene gas assay technique**

| Treatment | Ethylene produced (ppmv) | [2]Ethylene produced (nmol) | Nitrogenase activity (nmol $C_2H_4$/g/h) |
|---|---|---|---|
| Fresh[1] | 2.4 | 4.3 | 9.6 |
| Freezer | 0.3 | 0.6 | 1.3 |
| Room temp. | 0.7 | 1.3 | 3.1 |
| Outside | 2.0 | 3.8 | 9.0 |

1. Fresh samples were collected mid-April 1996, transported in ventilated sacks to Calgary 23 April 1996, tested early May 1996.
2. Lichens were collected from Mount Bickford, British Columbia in August 1995, immediately transported to Calgary, Alberta in ventilated sacks, air dried for 75 days then subsamples were stored for approximately 5 months under the following conditions: freezer, in the dark at ~-15°C; room temperature, in the dark in a ventilated sack at ~22°C. Outside, under normal climatic conditions and photoperiod as experienced in Calgary, Alberta from December to May 1995/96.
3. Tests on treated lichens were performed in early May 1996.
4. Fresh sample assayed in duplicate. Nitrogenase activity presented as average of two results.
5. Results corrected for measured headspace volume.

### Dark respiration and photosynthetic activity

Photosynthetic activity for both *Cetraria nivalis* and *Stereocaulon paschale* was observed to be highest in the "fresh" samples followed by the "room temperature" stored samples with the "outside" and "freezer" stored samples exhibiting the lowest levels (Table 2). The literature review did not reveal relevant references for comparison with our values. The values for the autoclaved samples indicated that there was some oxygen reaction with the theoretically non-viable thallus, possibly resulting from survival of some thallus segments. The use of mercuric chloride or formalin treated thallus for rendering the lichen non-viable should be considered for any future comparisons. The depressed photosynthetic activity of the "freezer" and "outside" stored samples was indicative of either a lower concentration of photobionts (algae), a photosynthetically impaired photobiont population, or a higher fungal biomass. There was also a relatively higher rate of dark phase respiration observed in these latter two treatments suggesting that active metabolism was occurring. Our conclusion is that this metabolic activity is likely from non-structural carbohydrate utilization and synthesis of proteins and other cellular constituents assumed lost or rendered inactive as a result of the storage conditions.

**Table 2. Photosynthetic response of *Cetraria nivalis* and *Stereocaulon paschale* subject to different storage conditions[1,2]**

| Sample | [1]Oxygen exchange rate (µl $0_2$/min/g dry weight)[3] | | |
|---|---|---|---|
| | Light phase $O_2$ removed | Dark phase $O_2$ removed | Photosynthesis $O_2$ produced |
| *Cetraria* – Fresh | 10 | 84 | 74 |
| *Cetraria* – Freezer | 61 | 84 | 23 |
| *Cetraria* – Room temp. | 99 | 144 | 45 |
| *Cetraria* – Outside | 165 | 192 | 27 |
| *Cetraria* – Autoclaved | 65 | 52 | –13 |
| *Stereocaulon* – Fresh | –2 | 88 | 90 |
| *Stereocaulon* – Freezer | 69 | 103 | 34 |
| *Stereocaulon* – R.T. | 59 | 101 | 42 |
| *Stereocaulon* – Outside | 80 | 92 | 12 |
| *Stereocaulon* – Autoclaved | 9 | 20 | 11 |

1. See Table 1, notes 1, 2 and 3 for collection and storage details.
2. All lichen samples were hydrated and incubated under low light conditions for 2–3 days prior to tests; test temperature was 21±2°C; light incubations were done at 5,000 to 7,500 lux in sealed 1.25 l acrylic containers (also used for dark incubation); wet weight were measured at test termination.
3. All rates based on an average of measurements made at 24 and 48 hours. Photosynthesis measured as difference between dark and light respiration in the sealed 1.25 l acrylic containers. Fresh samples performed in duplicate. Average of duplicate samples presented except second *Stereocaulon* – fresh result was discarded because of higher moisture content. Samples autoclaved (121°C, 15 min); positive photosynthesis response likely a result of wet lichen surviving autoclave treatment.

**Table 3. Results of the Yamamoto Thallus Tissue Culture Test to determine % of uncontaminated thallus segments exhibiting visible algal and fungal growth[1]**

| Sample | No. segments observed[2] | % with visible algal growth[3] | % with only visible fungal growth |
|---|---|---|---|
| *Cetraria* – Fresh | 130 | 65 | 35 |
| *Cetraria* – Freezer | 156 | 43 | 57 |
| *Cetraria* – R.T. | 104 | 53 | 47 |
| *Cetraria* – Outside | 122 | 50 | 50 |
| *Stereocaulon* – Fresh | 52 | 71 | 29 |
| *Stereocaulon* – Freezer | 120 | 61 | 39 |
| *Stereocaulon* – R.T. | 96 | 64 | 36 |
| *Stereocaulon* – Outside | 78 | 58 | 42 |

1 See Table 1, notes 1, 2 and 3 for details on collection and storage.
2 Only uncontaminated segments were used for tests. Contamination due to bacteria, yeast, mold and in some cases algae. The number of contaminated segments appeared similar between treatments (storage conditions).
3 Dominant algae component, *Trebouxia*, used for measurements.

### Tissue culture tests

Results from the Yamamoto tissue culture tests indicated that for *S.paschale* the "fresh" samples exhibited the highest percentage of segments with visible algal (photobiont) growth followed by the "room temperature", "freezer" and "outside" stored samples: differences among the latter trace treatments were minor (Table 3). A similar pattern was observed in the *C. nivalis* samples though the "freezer" samples exhibited the least growth of all. Differences between "room temperature" and "outside" storage conditions were minor for *C. nivalis*.

The results of the algal and cyanobacterial photobiont isolation test indicate that the "fresh" samples of *S.paschale* had the highest *Trebouxia* photobiont concentration (Table 4). The "fresh" sample value slightly exceeded the "room temperature" value and exceeded the "freezer" and "outside" sample counts by 5–6 times their value. The results suggest the photobiont population may have been negatively impacted in the "freezer" and "outside" samples by cold-induced stress or in the "outside" sample by excessive light exposure and/or freeze thaw cycles typical of Calgary winter climate. No cyanobacterial photobionts were detected. Species such as *Stigonema cyanobacteria* may have been below the detection limit for the test (i.e., $10^3$ Cell Forming Units/g) or the culture media was unsuitable for their growth. For Cetraria the "fresh" sample had a *Trebouxia* photobiont concentration slightly higher than the "room temperature" and "freezer" samples respectively. The algal population isolated from the "outside" *Cetraria* sample had the lowest concentration of *Trebouxia* cells.

**Table 4. Results of the algal and cyanobacterial photobiont isolation test measuring concentration of algal component [1,2]**

| Sample | Cell count (CFU × $10^5$/gdw 100 µm filtrate residue) Algae (*Trebouxia* sp.)[3] |
|---|---|
| *Cetraria* – Fresh | 62±15 |
| *Cetraria* – Freezer | 41±19 |
| *Cetraria* – R.T.[4] | 58 |
| *Cetraria* – Outside | 7.1±2.5 |
| *Stereocaulon* – Fresh | 41±15 |
| *Stereocaulon* – Freezer | 6.8±1.6 |
| *Stereocaulon* – R.T.[4] | 22±9 |
| *Stereocaulon* – Outside | 8.1±0.8 |

1. See Table 1, notes 1, 2 and 3 for details on collection and storage.
2. Photobiont isolation list measured for algal component only, cyanobacterial component was either not applicable (*Cetraria*) or not detected (detection limit $1\times10^3$ CFU/g).
3. Average of six replicates presented except *Cetraria*. CFU = Cell Forming Units.
4. Room temperature (R.T.) sample data is the average of duplicated replicates.

## SUMMARY OF RESULTS

Based on the preliminary results obtained, short-term storage under any of the methods examined appears technically feasible. In consideration of lichen sample performance and the practical aspects of lichen storage, it is suggested that "room temperature" storage of lichen is likely the best all-round form of remote short-term storage. The storage conditions had a varying impact on the lichen's photosynthesis, dark respiration and nitrogen fixation rates. Based on microscopic examination of tissue culture test thallus fragments and the relatively high concentration of algal cells detected in all of the samples thalli (e.g., >$10^5$ Cell Forming Units/g), it is hypothesized that any cellular or metabolic impacts originating from the various storage conditions and particularly that of cold induced stress, would not restrict redevelopment (growth) of the lichen thallus given favorable environmental conditions. Although reclamation *per se* was not a part of this investigation, the information obtained during the study can be analyzed with respect to implications it may have for reclamation attempts with the stored lichen samples.

## IMPLICATIONS FOR RECLAMATION AND POSSIBLE ALTERNATIVES

From a reclamation perspective, it appears that a combination of manual collection and remote storage under dry, cool conditions, combined with careful, on-site storage offers the most practical means of re-establishing disturbed lichen communities over the short term (e.g., one year). In order to reduce the potential for sample composting, and as such, optimize storage longevity, lichens should be air dried immediately following field. Under this regime, lichen stored on site could be spread over a recontoured road bed and the site further "seeded" with manually collected remotely stored lichen. Site preparation measures would have to be undertaken in order to encourage lichen establishment and prevent excessive windthrow of "seeded" lichen. Ideally sites should be well drained and slightly roughened to facilitate anchoring of lichen. It should be born in mind that these measures are primarily intended for short term disturbances.

While on-site storage of lichen from alpine environments has certain intuitive appeal, mechanical recovery using heavy equipment is difficult due to factors such as: the occurrence of near surface bedrock, the potential to bury lichen under rock and mineral soil, and the risk of creating an excessively mounded windrow of lichen and other alpine organic matter that effectively composts living tissue thus jeopardizing lichen viability.

Where roads are kept in use for more prolonged periods it is likely that viability of lichen stored dry in feed sacks at cool temperatures would gradually decline to a point where it had marginal value for "reseeding" disturbed alpine environments. Outside, remote storage of lichen does provide an alternative, however, it does require commitment of sufficient space and substrate to promote normal lichen activity. This additional space requirement may conflict with other reclamation and environmental interests. Alternatively, reclamation of lichen beds following prolonged development projects could be achieved by way of lichen transplants from thinned host communities in nearby, undisturbed locations. However, this approach obviously comes at the expense of the donor site and as such is of questionable value.

Finally, for all methods of lichen reclamation - using remote and/or on-site storage as well as host community transplants - there is some potential for artificial enhancement of lichen growth and consequently lichen recolonization through the use of soil amendments. *Cladina* spp. and *Hypogymnia* sp. lichens have variously been shown to respond positively to treatment with 2,4,D, thiamine, ammonium sulphate, inorganic nitrogen, and phosphorous fertilizers and gibberellic acid (Kauppi 1980, Pegau 1968, Barashokova 1964). Concerns have been raised about the potential short and long term consequences of soil amendments to lichen symbiosis and the larger ecosystem of which they are a part (Vagts et al. 1994, Ahmadjian 1993).

## ACKNOWLEDGEMENTS

The authors would like to express their thanks to Mr. Rob Staniland and Mr. Phil Pelletier of Talisman Energy Inc. for their advice, support and interest in conservation and reclamation of alpine habitats. We would also like to extend thanks and acknowledgment to Dr. D.H. Vitt for his assistance in lichen classification of samples obtained from the Mount Bickford site.

## REFERENCES

Ahmadjian, V. 1993. The Lichen Symbiosis. John Wiley & Sons, Inc. Toronto, Ontario. pp. 115–135.

Ahmadjian, V. 1967. Phycologia, 6 (2/3): 127–160.

Backmeyer, R. 1994. Peace/Williston Wildlife Compensation Program: Graham River Caribou Study. Peace/Williston Wildlife Compensation Program, B.C. Environment/B.C. Hydro, Prince George, British Columba. 220 pp..

Barashkova, E.A. 1964. Rapid renewal of stocks of fodder lichens with the help of growth stimulators. In: Problemy Seveva. Ret 2H Biol., 6: 64.

Bloomfield, M.I. 1979. The ecology and status of mountain caribou and caribou range in Central British Columbia. MS Thesis, University of Alberta, 218 pp.

Environment Canada. 1993. Canadian climate normals 1961–1990: Prairie provinces. Ministry of Supplies and Services Canada. 266 pp.

Huss-Danell, K. 1977a. Nitrogen fixation by *Stereocaulon paschale* under field conditions. Canadian Journal of Botany, 55: 585–592.

Huss-Danell, K. 1978. Seasonal variation in the capacity for nitrogenase activity in the lichen *Stereocaulon paschale*. New Phytology, 81: 89–98.

Huss-Danell, K. 1977. Nitrogenase Activity in the lichen *Stereocaulon paschale*: Recovery after dry storage. Physiology of Plants, 41: 158–161.

Hutchinson, W.A. 1969. *Stereocaulon:* Ecology and physiology of some boreal species and their isolated components. PhD Dissertation, University of Massachusetts, Massachusetts.

Kauppi, M. 1980. The influence of nitrogen-rich pollution components on lichens. Acta Universitatis Ouluenses. Biologica, 9: 1–25.

Kappen, L. 1973. Responses to extreme environments. In: The Lichens, V. Ahmadjian and M.E. Hale, eds. London Academic Press, Vol. 10, p. 311.

Larson, D.W. 1978. Patters of lichen photosynthesis and respiration following prolonged frozen storage. Canadian Journal of Botany, 56: 2119–2123.

Manseau, M., J. Huot, and M. Crete 1996. Effects of summer grazing by caribou on composition and productivity of vegetation: Community and landscape level. Journal of Ecology, 84: 503–513.

Pegau, R.E. 1968. Growth rates of important reindeer lichens on the Seaward Peninsula, Alaska. Arctic, 21: 255–259.

Richardson, D.H.S. 1973. Photosynthesis and carbohydrate movement. In: The Lichens, V. Ahmadjian and M.E. Hale, eds. Academic Press, Vol. 8, p. 249.

Russell, D.E., A.M. Martell and W.A.C. Nixon. 1993. Range ecology of the Porcupine Caribou herd in Canada. Rangifer, 8: 167.

Skogland, T. 1980. Comparative summer feeding strategies of arctic and alpine *Rangifer*. Journal of Animal Ecology, 49: 81–98.

Stevenson, S.K. and D.F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia. BC Ministry of Forests. Prince George, British Columbia. Land Management Report No. 23.

TERA. 1996. Large mammal surveys of the upper pine river/carbon creek watersheds. British Columbia, January–April, 1996. Unpublished Report. 20 pp.

Thomas, D.C., E.J. Edmonds, and W.K. Brown. 1996. The diet of woodland caribou populations in west-central Alberta. Rangifer, 9: 337–342.

Vitt, D.H., J.E. Marsh, and R.B. Bovey, 1988. Mosses, Lichens and Ferns of Northwest North America. Lone Pine Publishing, Edmonton, Alberta. pp. 156–253.

Wood, M.D. 1994. Seasonal habitat use and movements of woodland caribou in the Omineca Mountains, North Central British Columbia, 1991–1993. Rangifer, 9: 365–378.

Yamomoto, Y. 1987. Tissue culture of lichens. Proceedings of the Symposium of Tissue Culture of Lichen and Bryophyte. Nippon Paint Company, Osaka, Japan. pp. 14–25.

## *BIOGRAPHICAL SKETCHES*

***Randal Glaholt***

*Environmental Planner, TERA Environmental Consultants (Alta.) Ltd., 205, 925 - 7th Avenue S.W., Calgary, Alberta, Canada T2P 1A5*

Randal Glaholt, M.E.Des., P.Biol., is an ecologist and environmental planner working for TERA Environmental Consultants (Alta.) Ltd. He has a particular interest in the management and conservation of terrestrial and aquatic ecosystems where these are potentially impacted by human activities.

***Chris Meloche***

*Environmental Biologist/Microbial Ecologist, Clifton Associates Ltd., 300, 665 - 8th Street S.W., Calgary, Alberta, Canada T2P 3K7*

Chris Meloche, B.Sc., P.Biol., is an environmental biologist/microbial ecologist currently working as a Project Biologist at Clifton Associates Ltd. in Calgary, Alberta, Canada. His area of expertise includes the microbiological characterization of soil and groundwater, the design and implementation of treatability studies and monitoring programs of soils and groundwater contaminated with organic contaminants.

***Laura VanHam***

*Environmental Planner, TERA Environmental Consultants (Alta.) Ltd., 205, 925 - 7th Avenue S.W., Calgary, Alberta, Canada T2P 1A5*

Laura VanHam, B.Sc., is currently working on a Masters degree in Environmental Science at the University of Calgary. The focus of her research is wildlife habitat reclamation. In addition, she is employed as an Environmental Planner for TERA Environmental Consultants (Alta.) Ltd. in Calgary, Alberta, Canada.

# Project Habitat: ROW Management to Enhance Wildlife Habitat and Utility Image

George Hurst

The millions of acres on transmission and distribution rights-of-way (ROW) in North America provide an opportunity for utilities to enhance wildlife habitats. A variety of habitats occur on ROWs and provide habitat diversity and edge, which can increase biodiversity and density. Often, ROW plant communities are in early successional stages, which provide habitat conducive for insects and small mammals, and thus, form a prey base for associated predators. ROWs can serve as travel corridors. Project Habitat is an educational and community relations program that helps utilities enhance wildlife habitat on ROWs and earn positive recognition for their efforts. To accomplish the objectives of Project Habitat, members use integrated vegetation management programs that feature low-volume applications of selective herbicides (e.g., imazapyr).

*Keywords*: Project Habitat, habitat, imazapyr, integrated vegetation management, rights-of-way, utilities, wildlife

## INTRODUCTION

There are millions of acres of wildlife habitat on transmission and distribution rights-of-way (ROWs) across North America. These ROWs cross many different sites, soils, climates and biogeographic regions. ROWs traverse many different plant communities, such as wetlands, forests, prairies and agriculture fields, and they occur in many landscapes. ROWs provide an opportunity for wildlife habitat enhancement because tall trees cannot be grown there (Hurst 1994). With the new community relations program called Project Habitat, utilities can earn recognition for ROW management practices designed to enhance wildlife habitat while delivering essential electrical power.

## RIGHTS-OF-WAY HABITATS

Animal habitat is comprised of biotic and abiotic factors including a plant community that provides all or some of a species' requirements, such as food, cover, water, space and special features (e.g., nest cavity). Man's land use practices are often a major factor. Density and distribution of an animal population are a function of habitat type, quantity, quality and arrangement.

Plant communities vary greatly on ROWs and provide habitats for a variety of wildlife, both invertebrates (e.g., insects) and small to large vertebrates (e.g., mice, moose). For some small animals, such as grasshoppers and mice, ROWs can provide all habitat requirements (Hurst 1972). For larger animals, such as gray fox or white-tailed deer, ROW habitats may provide only some or seasonal requirements. ROW habitats may be important for one or more uses, such as dusting, nesting, brood-rearing, dispersing or foraging. Special uses include the comparatively open nature of ROWs as a place to dry-off after a heavy rain or a place to obtain radiant heat to warm up.

### Habitat features of rights-of-way

*Biodiversity*

ROW habitats are often old-field like or are in early plant successional stages because of disturbances such as mowing or spraying. Often, ROW habitats occur on rough terrain and have not been converted to intensive agricultural land uses, and thus provide essential habitats in an otherwise depleted area. In a landscape dominated by a mature forest, one would expect an increase in biodiversity because of different habitat types on ROWs. ROW habitats can affect species presence and abundance via increased interspersion and juxtaposition.

*Edge*
ROWs add much edge to a landscape. Edge is where different plant communities, or habitats, meet. For example, an edge occurs where a ROW and forest meet. The combination of a forest and old-field habitat provide a variety of food sources for wildlife. Some species are edge species, and you would expect more of these species present, particularly low mobile species. There also might be greater biomass. However, a lot of edge relative to total area has been found to be detrimental for other species, especially some birds. Increased predation of bird eggs and nestlings along ROW edges has caused low reproductive success rates.

*Wildlife openings*
ROW habitats are similar to wildlife openings, thus enhance an area for wildlife (e.g., variety of foods and cover). They are often used as travel corridors. This feature could be considered positive because of gene flow and connectivity, but also negative in that many predators hunt edges and predation rates could be increased. In addition, ROWs fragment large forested tracts, resulting in smaller blocks that are more accessible to man, the brown-headed cowbird (a nest parasite), and many predators. ROWs become human "roads" for snowmobiles, hunters and hikers, so they present opportunities and problems such as trespass or harassment.

**Habitat quality**
Habitat quality on ROWs varies from low (poor) to high (good) for a given species according to plant community composition and structure. Habitat quality varies with site/soil conditions, climate, size, location, etc. Plant communities on ROWs are man-made in many respects, depending on past use (e.g., farmed, mowed, grazed, burned, sprayed). Exotic species have been planted on or have invaded many plant communities, including those on ROWs.

Plant species composition, diversity or richness are important habitat attributes. Wildlife managers, ecologists and conservationists usually desire a wide plant species diversity. A ROW habitat dominated by dense broomsedge (*Andropogon virginicus*) or fescue grass (*Festuca* sp.) is undesirable for many species. Dense grass prevents erosion, is accessible to line crews and is not a danger to power lines, but it is low-quality habitat. Habitat quality would be greater for many species if there were a variety of grasses, sedges, forbs, vines, mosses, ferns, mushrooms and woody shrubs.

It is important to manage ROW plant communities so there is a great variety of forbs. (These are broadleaf weeds to some, but wildflowers or flowering plants to others.) Forbs, including legumes, provide green forage for insects, rabbits and deer. Forbs also provide seeds and fruits for a number of species; and a variety of flowering plants or wildflowers provide pollen, nectar, egg deposition sites and larval food sources for butterflies, moths, bees, wasps, etc. The biotic community on a ROW is enhanced by having a variety of flowering plants. In fact, the appeal or aesthetic value to people who view ROWs is enhanced. "What can be wrong if there are many beautiful flowers?" they might say. In addition, the greater plant species composition or richness would favor herbivores (e.g., grasshoppers, mice, rabbits, deer) that are eaten by songbirds, raptors, snakes, bobcat, foxes, coyote and wolf.

Plant community structure on ROWs is simplified because a mature forest cannot be permitted. Stratification, or number of layers in a ROW plant community, is reduced to three: litter, herbaceous and perhaps a shrub layer. Habitat niches are diminished compared to a mature forest, but the different habitat type (i.e., grass/forb) provides niches for an array of species not found in a mature forest. Plant density (number of stems per unit area) varies from many (thick) to few (sparse). Soil fertility and hydrology determine basic productivity, but man's treatments have impacted most plant communities.

How does this affect utilities? Their job is to deliver power to run America's factories, businesses and homes. ROWs are essential to this task. The goal of ROW management is to keep trees out of power lines. But ROW managers can, at the same time, improve the habitat for wildlife just by making slight adjustments to their management practices. This is what Project Habitat is all about.

## PROJECT HABITAT

Project Habitat was launched in 1995 as an educational and community relations program that helps utilities enhance wildlife habitat on ROWs and earn positive recognition in their communities for these efforts. The program is cosponsored by Quail Unlimited, the National Wild Turkey Federation, Buckmasters, Butterfly Lovers International and American Cyanamid Company. Twenty-three leading utilities are currently members of the program (see Table 1). Objectives of Project Habitat are to:

1. manage ROWs with an eye towards wildlife habitat,
2. increase biodiversity on or near ROWs,
3. involve local citizens in the effort, and
4. gain positive publicity for the participants.

To accomplish these objectives, members use integrated vegetation management (IVM) programs that feature low-volume applications of selective herbicides such as those with the active ingredient imazapyr. Imazapyr, found in ROW herbicides such as Arsenal[1] and Stalker[1], effectively controls many hardwood tree species such as oak, hickory and sweetgum, but does not kill blackberry, dewberry or other important wildlife plants.

**Table 1. Project Habitat member utilities**

| |
|---|
| American Electric Power |
| Atlantic Electric |
| Central Hudson Gas & Electric Corporation |
| Central Illinois Public Service |
| Cinergy/Cincinnati Gas & Electric Company |
| ComEd |
| Consumers Energy Company |
| Entergy |
| Florida Power & Light Company |
| Gainesville Regional Utilities |
| Georgia Power Company |
| Georgia Transmission |
| Gulf Power Company |
| Houston Lighting & Power Company |
| Kentucky Utilities |
| Mississippi Power Company |
| Nantahala Power & Light Company |
| Niagara Mohawk |
| Northern States Power Company |
| Santee Cooper Public Service |
| South Carolina Electric & Gas |
| Tennessee Valley Authority |
| Virginia Power Company |

## Herbicide effect on habitat

I have conducted several research projects on the impact of intensive pine plantation management, including the use of several herbicides to control woody and/or herbaceous competitors of pine, on plant communities in Mississippi and Alabama (Hurst 1989). We documented that the impact of herbicides (Velpar[2], Arsenal) on number of plant species, plant coverage and amount of white-tailed deer forage was limited to the first growing season after application. Most plant communities recovered and had characteristics similar to areas not treated with a herbicide during the second growing season (Copeland and Hurst 1986, Hurst 1987, Blake et al. 1987, Wilson et al. 1993).

Legume species (including *Lespedeza* spp.) were observed to be tolerant to several rates of aerial application of Arsenal (imazapyr) in young pine plantations in Mississippi. In addition, by controlling the abundant overhead and highly competitive hardwood brush, many forbs were released from competition to grow (Hurst 1987). Many species of the legume family are tolerant to Arsenal (Shaner and Mallipundi 1991, Witt 1991). Studies in South Carolina reported legume tolerance to Arsenal; percentage cover by legumes (e.g., lespedeza, partridge pea) was similar between Arsenal-treated and control, or untreated, plots. Coverage by composites was much greater on Arsenal-treated versus control plots, and coverage by other forbs was similar between Arsenal-treated (39%) and control (24%) plots. Finally, insects, important dietary items for many birds and particularly their young nestlings or chicks, were found to be equal to or more abundant on Arsenal-treated plots than control plots (Feken 1995, Hawkes 1995).

## Using an integrated program

Managers have their choice of different methods of vegetation control including mechanical (mowing, hand-cutting) or chemical (high or low-volume foliar, low-volume aerial, low-volume backpack, basal bark). Each method has advantages and disadvantages, which are presented in a Project Habitat booklet entitled "A Better Way for Rights-of-Way". Utility company ROW managers should work with contractors and/or company representatives to evaluate the ROW vegetation, problems and habitat condition, then write a management plan. Short- and long-term goals regarding vegetation condition (habitat) should be considered.

Project Habitat focuses on the use of low-volume herbicide control versus mechanical control with bush-hogs, for example. Mowing or bush-hogging plant communities on ROWs instantly destroys habitat. All standing vegetation is cut and some is killed while some brush is only top-killed. Some wildlife, especially those in nests, could be killed. Foods and cover are instantly removed, and the resulting dead plant material is placed on the ground where it acts as a mulching material that impedes the growth of some plants. Like many standard high-volume herbicides, mowing tends to favor development of dense grass communities with a lower density and diversity of flowering plants.

Project Habitat recognizes that given species composition, density, average height and other factors, a manager may choose mechanical control. A combination of bush-hogging and spraying may be needed. Following bush-hogging and sprouting during one growing season, a selective herbicide can be used to control the tree species. Thereafter, a low-volume broadcast application with a selective herbicide or individual stem treatments can be used to maintain control of tree species.

Low-volume applications — those using less than 100 gallons per acre — can be made with standard hydraulic equipment and may be as simple as changing to a nozzle that delivers less material. In addition to having less impact on ROW habitat, many utilities have found low-volume programs lower long-term management costs.

An IVM program including low-volume applications also complies with the Environmental Protection Agency's Environmental Stewardship Strategy for Electric Utility ROWs by reducing the pounds of active ingredient per unit of land area. High-volume spraying (e.g., greater than 100 gallons/acre) places more active ingredient on ROWs. High-volume applications tend to produce dense grassland communities that contain

1 Trademark, American Cyanamid Company.

2 Trademark, The DuPont Company.

few plant species and are lower quality habitat. Low-volume has less impact on plant communities. Project Habitat involves IVM because it features not only low-volume application, but advocates fewer applications over time. With proper evaluation and planning, the number of applications can be reduced and crews can be taught not to apply herbicide to important wildlife shrubs such as blueberry or huckleberry.

### Other opportunities for habitat enhancement

Project Habitat offers opportunities for habitat enhancement, such as planting supplemental food plots, planting wildflowers on sections of ROW that have high visibility to the public, erecting bluebird nesting boxes with predator guards or leasing improved habitat to hunting clubs. The National Wild Turkey Federation and Quail Unlimited — both Project Habitat sponsors — work closely with utilities to help those interested seed portions of ROWs to preferred food and cover plants.

In New York, Niagara Mohawk, an electric utility and Project Habitat member recognized with an award for the best ROW in 1996, is focusing its ROW vegetation management practices to expand the range and density of lupine (Lupinus spp.). This legume is essential for the existence of an endangered species of butterfly, the karner blue. In this case, vegetation management and research and development divisions are working with state and federal agencies to enhance a plant for a butterfly, and a herbicide is being used (see paper by Finch in this symposium).

A new herbicide, Plateau[1] herbicide, is currently being used for native prairie renovation and restoration. Imagine: a herbicide being used to kill nonindigenous plants such as Johnsongrass, foxtails, crabgrasses and tall fescue so that native prairie species such as little bluestem, Indiangrass, blue grama and other grasses, wildflowers and legumes can be established to form a prairie community. ROWs transverse many regions where native prairies once occurred and offer an opportunity for vegetation managers to work with prairie restoration organizations.

### Utility image

With deregulation and increasing competition, utilities are in a state of change. Public relations and corporate image are increasingly important considerations. Project Habitat offers members an opportunity for positive publicity and recognition for wildlife-friendly management practices. To help them capitalize on public relations opportunities, Project Habitat offers members a number of tools, including:

1. A Project Habitat Community Relations Guide, which outlines approaches utility companies can use to involve media, local community groups and landowners.
2. Project Habitat statement stuffers, which explain the program to utility customers and landowners.
3. The "Native Plants for Wildlife" handbook, a guide to identifying species that provide good wildlife habitat and are released through Project Habitat management techniques.
4. Publicity in the form of news releases to local newspapers and industry publications.

A highly effective method for a utility to engage civic, conservation groups and ROW landowners or community members is a dinner seminar to explain vegetation management practices and impacts. A utility manager, chemical company representative and wildlife professional can make presentations. Several topics can be addressed including pros and cons of mechanical versus chemical vegetation control, toxicity of herbicides, requirements for good habitat and local concerns.

The public wants — even demands — low-cost, safe and dependable energy. And most people are concerned about wildlife and wildlife habitat. Thus, utilities have an opportunity to provide both energy and improved habitats on ROWs through programs such as Project Habitat.

1 Trademark, American Cyanamid Company.

## ACKNOWLEDGMENTS

I thank the many graduate students who collected the field data. I thank American Cyanamid Company for their support.

## REFERENCES

Blake, P.M., G.A. Hurst, and T.A. Terry. 1987. Responses of vegetation and deer forage following application of hexazinone. Southern Journal of Applied Forestry, 11(4): 176–180.

Copeland, J.D. and G.A. Hurst. 1986. Deer forage on pine plantations after intensive mechanical and chemical site preparation. Proceedings of the Southern Weed Science Society, 39: 237.

Feken, M.A. 1995. Wildlife habitat and Arsenal herbicide: Response of food and cover attributes important to northern bobwhite. M.S. Thesis, Clemson University, Clemson, South Carolina. 79 pp.

Hawkes, A.W. 1995. Northern bobwhite (*Colinus virginianus*) response to treatment of a South Carolina pine plantation with Arsenal applicators concentrate. Ph.D. Dissertation, Clemson University, Clemson, South Carolina.

Hurst, G.A. 1972. Insects and bobwhite quail habitat management. Proceedings of the National Bobwhite Quail Symposium, 1: 65–82.

Hurst, G.A. 1987. Vegetative responses to imazapyr for pine release. Proceedings of the Southern Weed Science Society, 40: 247.

Hurst, G.A. 1989. Forestry chemicals and wildlife habitat. Forest Farmer, 48(4): 10–11.

Hurst, G.A. 1994. Rights-of-way for wildlife. Bulletin No. 20, National Wild Turkey Federation, Edgefield, South Carolina. 8 pp.

Shaner, D.L. and N.M. Mallipundi. 1991. Mechanism of selectivity of the imidazolinones. In: The Imidazolinone Herbicides. D.L. Shaner and S.L. O'Conner, eds. CRC Press, Boca Raton, Florida. pp. 91–102

Wilson, L.M., B.D. Leopold, G.A. Hurst, and R.M. Watkins. 1993. Plant species richness following mechanical or chemical site preparation in eastern Mississippi. Proceedings of the Southern Weed Science Society, 46: 177.

Witt, J.S. 1991. Forestry herbicides used for site preparation: Effects on wildlife habitat. M.S. Thesis, University of Georgia, Athens, Georgia. 102 pp.

## *BIOGRAPHICAL SKETCH*

***George Hurst***

*Department of Wildlife and Fisheries, College of Forest Resources, Box 9690, Mississippi State University, Mississippi State, MS 39762, USA*

Dr. George Hurst is a Professor in the Department of Wildlife and Fisheries, College of Forest Resources, Mississippi State University. He has been conducting research on relationships of forest management practices to wildlife (deer, turkey, quail, songbirds, squirrels, rabbits, etc.) habitat conditions and population levels since 1972. He has conducted research on impacts of forest herbicides on deer forage abundance, plant species composition, and plant community characteristics. George has served as Project Leader for the Mississippi Cooperative Wild Turkey Research Project since 1984.

# A Five-Year Spanish Research Project on Bird Electrocution and Collision with Electric Lines

**Jorge Roig-Solés and Víctor Navazo-López**

The project, which could be considered unique world-wide for its scope and magnitude, was carried out in different environments of natural protected areas in Spain during a period of five years (1991–1995). The project objectives were to evaluate bird accidents at powerlines, to identify the causal factors and to develop protection measures. In order to establish the extent of the problem and to see which technical factors were involved, 21,000 structures and 520 power line spans were surveyed and one thousand hectares were monitored. Also one thousand hours of video film were dedicated to the observation of birds perching on electric structures, which were equipped with experimental devices to prevent electrocution. Besides the size of the bird, the frequency of electrocutions depends on the habitat and the design of tower. Birds being more prone to electrocution are those that most frequently perch on high vantage points. The mortality for collision, however, depends on the characteristics of the bird species. Some species are not very prone to collision, and others much more so. The efficiency of different protection systems is discussed, as well as the definition of the optimal policy for the construction of new lines and for the protection of the existing ones. Promoters of the project were the electric utility companies Sevillana, Iberdrola and Red Eléctrica, supported by different environmental agencies. The research was planned and carried out by the Spanish Superior Council of Scientific Research.

*Keywords*: Birds, electrocution, collision, powerlines, protection measures, mortality

## INTRODUCTION

Birds and powerlines interacted from the moment the powerlines first appeared. Since they have become a ubiquitous part of every type of landscape, powerlines and their supports (small distribution structures or large transmission structures) are used by many species as perches (high spots to look over a wide area of territory), resting points, and even nesting sites. In some areas, the ongoing transformation of the natural environment has led to a reduction in the number of natural supports for the normal activities of many birds: i.e., trees. Electricity structures have become excellent substitutes. This frequent presence of birds on powerlines often causes problems to the electric installations, problems that are not always given due consideration.

Greater consideration has been given, however, to the effect of these installations on birds. This is because birds, which have played a leading role in society's increasing sensitivity towards nature conservation, may be directly affected by overhead powerlines in their natural environment. The number of bird accidents recorded at electrical installations has led to growing concern among all those involved in the transmission and distribution of electricity and in nature conservation, as well as among researchers. Research has shown that power line accidents, either by collision or electrocution, are in some cases the most important cause of death in some species of birds, and have therefore played an important part in the reduction of their population. Bird electrocution at powerlines is caused either when the bird simultaneously touches two conductors or, more often, when it touches a conductor at the same time as it grounds the current by touching part of the metal support structure. Electrocution events are insignificant for powerlines of more that 66 kV, because there is too great a distance between conductors and cross arms. Electrocution is frequent in lower-voltage lines, especially where the chain of insulators is very short or where the layout of the conductors at the structure allows the bird to make simultaneous contact between conductor and structure. The result is almost always the death of the bird. Birds of medium or large size, especially raptors, are especially prone to these accidents, both because of their size and their frequent use of the structures as perch.

Collisions occur when birds in flight are unable to avoid the cables and fly into them. The result is usually fatal, although sometimes the bird is only injured. The probability of birds to suffer this sort of accident depends basically on the morphology of the different species (bulk, weight), on their flocking habits and flight behaviour. Collisions occur in transmission lines when, in poor visibility, the birds gain height suddenly to avoid the conductors and then come up against the much thinner ground cable. Birds most prone to this type of accident are those that habitually flock together, such as water birds and steppeland birds, crepuscular or nocturnal birds, and those that form large temporary flocks in feeding areas. Although collisions have been recorded for raptors this seems to be the exception rather than the rule.

It should not be forgotten, however, that, except in very special cases, bird accidents at powerlines are not the prime cause of population reductions in wild birds. Their effect, albeit significant, is not comparable to that of widespread habitat loss, which remains the main cause of the world-wide reduction in species, both in birds and in other animal and plant groups. Studies carried out in various countries on the number and type of birds killed by overhead lines do show the high significance of the problem in some localities and its great importance world-wide. Spain is no exception in this respect. The sheer wealth of Spanish bird life, enhanced by the fact that the Iberian peninsula serves as one of the main bird migration routes between Europe and Africa, means that bird accidents at powerlines are one of the most important environmental problems in the operation of power transmission and distribution networks in Spain.

Much of the study and monitoring of this problem in Spain has been pioneer work, because of its outstanding contributions to the greater knowledge of causes and effects. The year 1982 was a milestone year because an exhaustive monitoring of bird deaths at powerlines was carried out in Doñana National Park and its surrounding area. The aim was to assess the causal factors of the accidents and the effect on certain bird populations — particularly raptors — and also to come up with solutions. The study, conducted by Doñana Biological Station, an institute belonging to the Consejo Superior de Investigaciones Científicas (C.S.I.C.) clearly revealed the impact of some powerlines on species as important as the Spanish race of the Imperial Eagle. The fact that this bird was in imminent danger of extinction drove the Doñana Park Administration and the electricity company Sevillana de Electricidad to take urgent measures. The effectiveness of the measures taken — burying the most dangerous cables underground or replacing them by powerlines of braided cables — soon became evident: the mortality of young Imperial Eagles during the first months after leaving the nest fell in Doñana from 83% to a scant 20%.

**Table 1. Bird electrocution risk factors related to structure design**

| Primary factors | Secondary factors |
|---|---|
| Position of insulators | Structure height |
| Existence of jumpers | Layout of conductors |
| Existence of top-mounted circuit-breaker | Form of cross arm |
| Structure construction material | Existence of column-mounted circuit-breakers |

**Table 2. Determinant factors of bird collision risk with powerlines**

| Primary factors | Secondary factors |
|---|---|
| Birdlife composition | Structure height |
| Habitat characteristics | Structure layout |
| Existence of ground cables | Line voltage |
| Proximity to points of birds concentration | |

## THE PROJECT

In 1991, three Spanish electricity companies, Compañia Sevillana de Electricidad, Iberdrola and Red Eléctrica de España, promoted a research project aimed at co-ordinating and promoting the studies on bird accidents at powerlines. This initiative led to the signing of a collaborative agreement between the three companies and the Higher Council for Scientific Research (C.S.I.C.). The collaboration of the C.S.I.C. was essential as it possesses the technical and human resources for the development of the work and a wealth of experience in research work in this field.

Apart from the C.S.I.C. work, the promoting companies carried out support research work on their own account and either developed or gathered information on the prototype corrective measures that were the object of the project.

The project objectives provided for in the agreement were:

- Evaluate quantitatively and qualitatively the deaths produced by overhead powerlines.
- Identify the causal factors of bird collisions with powerlines and the structure design factors that affect the degree of electrocution risk.

- Develop protection measures of a reasonable cost to avoid or reduce the adverse effects of powerlines on birds, and determine the factors to be taken into account in the designing of new structures and lines to minimize the risks of bird accidents.

## METHODOLOGY

The research was designed to study the two kinds of bird accidents at overhead lines, electrocution and collision. As a response to the first two objectives for research on electrocution and collision ("Evaluate quantitatively and qualitatively the deaths produced by overhead powerlines" and "Identify the factors involved") areas were selected based on their suitability for studying these variables and for carrying out exhaustive field work.

The research method corresponding to the third objective ("Develop protection measures") varied according to whether electrocution or collision was at issue. To evaluate anti-electrocution protection measures a mock-ups were implanted to observe the behaviour of birds on structures with the measures fitted. The efficiency of the measures seen to be most useful in the mock-ups was finally evaluated under real conditions. The responses of anti-collision measures were directly evaluated under real conditions.

The specific field work areas were limited to protected sites of natural interest. They were selected in accordance with the density and species of birds, the presence of diverse types of powerlines and the potential for bird accidents. For the electrocution study, five protected sites of natural interest were chosen. For collision studies, another five were chosen, two of which were the same as those chosen for electrocution studies.

The birdlife of these areas is quite varied in terms of species and density. Bird communities are represented by various habitats, including: different types of wetland, natural Mediterranean woodland, open Mediterranean woodland cleared of undergrowth for grazing, treeless plains, extensive farmland, and mountains. Within these areas a selection was made of 30 km of transmission lines and more than 3,000 structures of distribution lines. The goal was to assess a wide-ranging diversity of situations involving factors such as density and variety of bird species, environmental characteristics of the habitats and the potential danger of the lines, among others.

The field work was undertaken in two stages. The first stage was an attempt to quantify bird mortality in both types of accidents and gain an in-depth knowledge of the causal factors of such mortality. This involved more than 21,000 structure checks throughout the working area and the examination of one thousand hectares of ground under 520 spans to look for collision victims. After laboratory testing of the anti-electrocution solutions proposed, those showing the best laboratory results were then tested in the second phase, involving the monthly check of about 300 modified structures and 14 modified spans, cross checked against a control of 200 unmodified structures and 16 unmodified spans.

The first stage of the electrocution study took two years. Bimonthly searches were carried out on predetermined routes of selected structures in each study area, including a first search to clear the ground. This gave information on the seasonal variation of bird mortality. All victims found in these searches were systematically collected and their remains were subjected to a morphological analysis to determine the species, sex and age of each one. Estimates were concurrently made in various areas of the amount of bird remains that would not show up because of carrion eaters, thereby arriving at the estimated rate of mortality at each structure in a given period of time.

Information was also gathered to give weighted figures on death rates and the danger of the installations, in terms of variables such as bird characteristics (species, age, sex), structure type (structure of the central column, characteristics of the insulators, existence of jumpers), habitat type, and the bird density in each zone.

The laboratory work, aimed at testing the effectiveness of the various anti-electrocution measures, involved the collaboration of a public organisation, which provided birds from a wild animal recovery centre and large, flight cages in which structures were installed with 4-m columns joined by cables for assessing various configuration modifications. The measures were installed on five structure types: four straight-through structures and one with a top-mounted three-wire circuit breaker. The modifications assessed out were either prototypes used for some time without rigorous certification of their effectiveness, or devices expressly designed by technicians of the companies promoting the project.

Two continuously filming video cameras provided information on the behaviour of various species in the cages, the part of the structure used for perching, and the time spent perching. Nearly 1,000 film hours were obtained, which established how the structures were used by the most accident-prone species, and permitted an evaluation of the effectiveness of the various measures before fitting them on live powerlines.

Once the effectiveness of the various corrective measures had been tested on the laboratory structures, the ones with the best results were fitted on structures in three of the areas, with unmodified control structures being maintained in all cases to verify the results. The same methodology used in the first phase was then repeated, along with monthly sampling, to determine mortality rates with both structure types.

The information obtained from these samples was compared statistically with the results of the first fieldwork stage. This comparison allowed specific, sound conclusions to be drawn on the real effectiveness of the corrective measures put into practice.

In the collision study the sample unit was the span delimited by two consecutive towers, rather than the structures themselves as in the electrocution study.

In the first field-work stage of the collision study the objective was to estimate bird mortality and its causal factors, so a similar methodology to that in the electrocution study was followed in terms of sampling frequency, valuation of bird density, categorisation of the victims, lines and habitats and an estimation of those remains that never came to light because of carrion eaters or thick vegetation. Records were also taken of the flight height of the birds in relation to the cable height of the lines studied. Given that the victim could fall some distance from the line after the impact, the sampling zone was a 50-m band — limited by two lines parallel to the power line — which was then searched in zigzag fashion.

Once real mortality was quantified in the sections studied, a start was made in late 1993 on marking 14 spans of the lines in three areas. The set of solutions developed was geared towards increasing the visibility of the ground cable (400 kV line) or conductors (two 132 kV lines). The fitting of these markers posed great problems, since it involved cutting off the current, and this led to delays in project deadlines.

## ELECTROCUTION STUDY RESULTS

The selection of field work areas for the electrocution study was made so as to reflect a diversity of habitats and bird communities, where there was likely to be a high accident risk: the saltmarshes and hills of the Entorno de Doñana, the Marismas del Odiel, the natural and open Mediterranean woods of the Sierra de San Pedro and Monfragüe and the pastureland of treeless plains in the Llanos de Cáceres.

The estimates of bird mortality rates at structures varied widely. This variation occurred when the counts of the first searches — to clear the ground — were taken into account, or only the results of the periodic searches thereafter, or when both sets of data were combined. Different results also occurred if statistical allowance was made for victim remains that did not come to light because of carrion eaters.

It was obvious that it would not be possible to obtain trustworthy mortality rates with a single clearing-up run, because such data would serve only to pinpoint hotspots, and that it was essential to make an estimate of the victims that would not be recorded in the field work.

Among the factors considered, *a priori*, as determining ones in bird electrocution, the first and foremost was the technical characteristics of the structures.

Lack of standardisation in structure design led to great difficulties in terms of evaluating the scope of the problem and gathering information relating accidents to structure type. In the context of this study alone more than eight hundred types were counted. The analysis centred on the identification of the effects of each of the structure elements, so that the danger of each structure could be obtained by summing the elements of which it is composed.

The structure construction material, the layout of the insulators, or the presence of jumpers over the upper cross arm were shown to be the most important danger factors. Wooden structures with no ground cable were shown to be safer than the metal ones because they are poor conductors. Structures with rigid insulators are more dangerous than structures with hanging ones, and jumpers over the cross arm, whether in mooring posts or in circuit breakers, increase the danger of electrocution, as shown in Table 4.

**Table 3. Bird electrocutions recorded in the first study phase (clearing-up run)**

| Species | No. recorded |
|---|---|
| Azure-Winged Magpie (*Cyanopica cyanus*) | 1 |
| Barn Owl (*Tyto alba*) | 6 |
| Black Kite (*Milvus migrans*) | 20 |
| Black Stork (*Ciconia nigra*) | 1 |
| Bonelli's Eagle (*Hieraetus fasciatus*) | 1 |
| Buzzard (*Buteo buteo*) | 40 |
| Cattle Egret (*Bubulcus ibis*) | 10 |
| Eagle Owl (*Bubo bubo*) | 1 |
| Goshawk (*Accipiter gentilis*) | 2 |
| Griffin Vulture (*Gyps fulvus*) | 1 |
| Imperial Eagle (*Aquila adalberti*) | 1 |
| Jackdaw (*Corvus monedula*) | 2 |
| Kestrel (*Falco tinnunculus*) | 5 |
| Kite spp. (*Milvus* spp.) | 11 |
| Lesser-Black-Backed Gull (*Larus fuscus*) | 1 |
| Magpie (*Pica pica*) | 1 |
| Peregrine Falcon (*Falco peregrinus*) | 4 |
| Raven (*Corvus corax*) | 39 |
| Red Kite (*Milvus milvus*) | 24 |
| Short-Toed Eagle (*Circaetus gallicus*) | 1 |
| Spotless Starling (*Sturnus unicolor*) | 1 |
| Tawny Owl (*Strix aluco*) | 8 |
| White Stork (*Ciconia ciconia*) | 27 |
| Unidentified | 11 |
| Total | 219 |

**Table 4. Average mortality rates (number of birds per structure/year) estimated for different basic designs for distribution line structures**

| Basic structure designs | No. bird deaths/year |
|---|---|
| Straight-through structure with hanging insulators | 0.03 |
| Straight-through structure with rigid insulators | 0.38 |
| Mooring structure with jumpers under the cross pieces | 0.12 |
| Mooring structure with jumpers over the cross pieces | 1.12 |
| Structure with top-mounted circuit breaker | 1.12 |

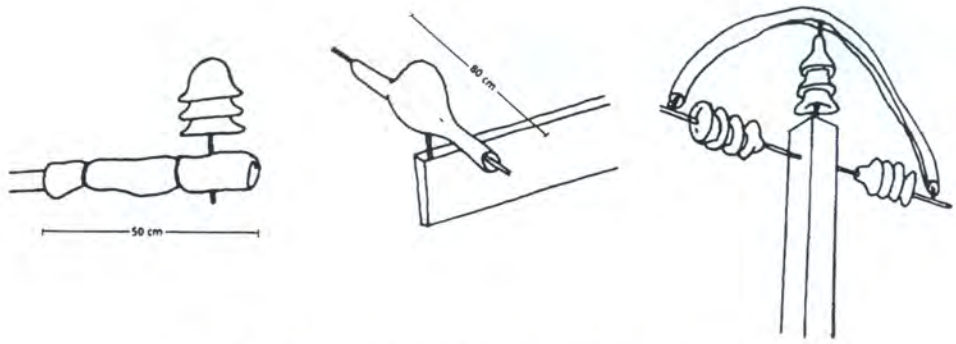



Fig. 1. The most effective anti-electrocution measures.

Other structure characteristics, such as the layout of the conductors, the existence of jumpers below the cross beams or column-mounted circuit breakers, are less influential factors in the danger of structures. In this respect, the existence on a structure of some of the most dangerous features may give rise to a bird mortality up to 35 times greater than that estimated for structures without such features. Analysis of electrocution risk in terms of the technical characteristics of the structures allowed us to classify all known designs in five danger categories:

1. Structures with top-mounted circuit breaker
2. Structures with one or more jumpers over the cross beam
3. Structures with at least one rigid insulator
4. Structures with jumpers below the cross beam
5. Straight-through structures with hanging insulators

Structure design is especially diverse in those areas with many privately run lines. These lines also have the greatest number of dangerous designs for birds. But any estimate of electrocution risk is always relative, inasmuch as the danger of a structure depends ultimately on the presence in the area of birds liable to perch on it. In this sense no clear relationship was shown between the abundance of birds in the working areas and the mortality recorded. More decisive was the specific make up of the birdlife in the areas studied and the behaviour differences between species.

Birds most prone to electrocution are those that most frequently perch on high vantage points. This is the case of diurnal raptors, which account for more than half of the recorded deaths, and also crows, storks and nocturnal raptors. Among these species, size is also a danger factor. Electrocution is commonest in large species, which are most likely to make simultaneous contact between structure and conductor.

Laboratory experience showed that, in simple circuit lines, the safest design for all species is the staggered-arm type with hanging insulators and, above all, the one known as "Canadian" (hanging insulators with staggered conductor layout and sloping cross arms). This proven fact means we can safely claim that there are structures that would minimize electrocution risk in newly installed powerlines.

**Table 5. Electrocution risks related to habitat groups**

| High | Medium | Low |
|---|---|---|
| Woods | Extensive cereal farmland | Eucalyptus woods |
| Open woods | Fallow land | Farmland |
| Wetland | Pastureland | |
| Scrubland | Built-up areas | |

Other measures designed to reduce electrocution risk were tested in the laboratory. Deterrent solutions were tested (designed to make it more difficult for birds to perch on the most dangerous parts of the structure), as well as the insulation of conductors and/or structures and mixed deterrent/insulation methods, analysing the cost, effectiveness and difficulties of various arrangements.

The insulation of cross arms or insulators and conductors, on structures with rigid insulators, and the insulation of the whole structure on structures with a top-mounted three-wire circuit breaker, turned out to be the most effective measures. The deterrent group, tried out only on structures with hanging insulators, showed less satisfactory results. But it was without doubt the field work that really showed the reliability of the various measures. Eight different measures were tested on the most common structures.

The results of the deterrent group, fitted on structures with hanging insulators and a staggered layout, were not very conclusive, so there are no firm grounds for recommending the fitting of protection measures on this type of structures. Neither were very conclusive results obtained with other deterrent measures fitted on structures with jumpers under cross pieces (deterrent "strips") and on top-mounted circuit breakers ("rods"). Taken as a whole, insulating measures showed themselves to be much more effective, both that used on structures with rigid insulators (covering of insulator and conductor on structures with "0" mounting or, on structures with "1" mounting, insulating plate below the central insulator and blanket covering of side arms of the cross pieces), and that used on

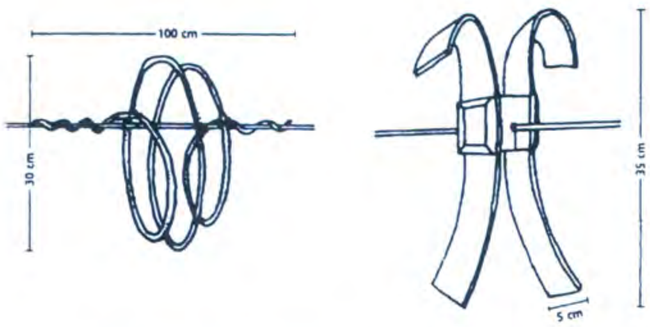



Fig. 2. The most effective anti-collision devices.

structures with jumpers over cross pieces (which were insulated with a geo-textile blanket).

At any rate the anti-electrocution measures did not prove to be equally effective for all species: on modified structures deaths of small raptors fell less than deaths of larger raptors.

The permanent effectiveness of the measures is in any case determined by how long the materials last and how long the devices continue to work as when fitted. It is therefore very important that follow-up and monitoring procedures be established to guarantee that the desired effects are attained by these measures, and equally important to use wherever possible devices little prone to degradation, such as barriers designed to deter perching. For newly installed powerlines the best solution is the range of safe designs combining effectiveness and durability, such as the Canadian-type structure.

Fig. 3. Structure design considered as the safest: Canadian cross arm with hanging insulators.

## COLLISION STUDY RESULTS

The work on collision risk shows that the overall effect of overhead transmission powerlines on birdlife is relatively low, very localised in area and, to a certain degree, easily reduced by marking the ground cable or the conductors. Its main impact is related to the abundance of bird species prone to collision with powerlines.

The areas chosen for this study represent different habitats where there was likely to be a high incidence of this sort of accident: a coastal saltmarsh with dense wader flocks (Marismas del Odiel) an inland reservoir with many water birds (Orellana), open Mediterranean woodland with large flocks of cranes and other wintering species (Valdecaballeros), open pastureland with a birdlife characteristic of treeless plains, especially bustards (Llanos de Cáceres) and a mountain area with a dense and varied raptor population (Foz de Lumbier).

**Table 6. Bird collision risks related to habitat groups**

| High | Medium | Low |
|---|---|---|
| Open woodland | Extensive cereal farmland | Woods |
| Wetland | Fallow ground | Scrubland |
| Treeless plains | Farmland | |
| Rubbish dumps | Built-up areas | |

The results show clear differences between collision mortality rates in each area: gross values range from no victim, in Foz de Lumbier, to the 25 victims per line/year in the most dangerous section of a distribution line in the Marismas de Odiel.

This variability seems to be very closely related to the characteristics of the habitats crossed by the lines and to the bird species present and their behaviour, more so even than to the characteristics of the powerlines themselves. However, there are some technical and physical aspects of the lines that do seem to bear some relation to the rate of bird accidents. Thus, a factor that other studies point to as weighing heavily in the danger of the line is the presence or absence of ground cables, since most collisions involve birds flying into this line rather than into the main cables. The number of horizontal plains or levels delimited by the cables may also influence collision risk, because it is after all a decisive factor in the size of the obstacle, although no firm conclusions have been drawn on this question.

Results of the study show that some species are little prone to collision (raptors and crows, for example) and others very liable to this type of accident (Great Bustards, Little Bustards, Common Cranes, flamingos, storks and certain waterbirds) either because of their flight characteristics, size and habitual flocking behaviour or their tendency to form temporary flocks in breeding and/or feeding areas (Table 7). Methodological aspects such as search frequency, the width of the

**Table 7. Bird collisions recorded in the first study phase**

| Species | No. individuals |
|---|---|
| Black Tern (*Chlidonia niger*) | 5 |
| Black-Headed Gull (*Larus ridibundus*) | 1 |
| Common Crane (*Grus grus*) | 11 |
| Flamingo (*Phoenicopterus ruber*) | 5 |
| Great Bustard (*Otis tarda*) | 16 |
| Griffin Vulture (*Gyps fulvus*) | 1 |
| Lapwing (*Vanellus vanellus*) | 1 |
| Lesser-Black-Backed Gull (*Larus fuscus*) | 1 |
| Little Bustard (*Otis tetrax*) | 10 |
| Mallard (*Anas platyrhynchos*) | 2 |
| Moorhen (*Gallinula chloropus*) | 1 |
| White Stork (*Ciconia ciconia*) | 8 |
| Willow warbler/Chiffchaff etc. (*Phylloscopus* spp.) | 2 |
| Woodpigeon (*Columba palumbus*) | 9 |
| Unidentified | 2 |
| Total | 86 |

terrain searched or the training of the observers in detecting victims or bird remains lead to under- or over-estimations of the mortality of certain species or bird-size categories. Thus, for example, a single or clearance search was shown to be insufficient. A realistic estimate of remains removed by carrion eaters is essential for a duly weighted estimate of mortality rates.

Anti-collision measures tested showed very disparate levels of effectiveness. In general, and according to the results of other studies, it can be said that the size of the marking device has no direct influence on overall results but it does affect the frequency along the length of the line.

Of the three methods tried out, the fitting of white spirals 30 cm in diameter, laid out in alternate direction on the ground cable every 10 m, was shown to be the most effective. The white spirals were tested on three spans, leaning three control spans between the test spans. The number of collisions in the spans with spirals were eight before the fitting of spirals and four after the fitting of spiral. The number of collisions in the control spans, always without spirals, were four before the fitting of spirals in the test spans and 21 after the fitting of the spirals in the test spans. Hanging black plastic hoops, 70 cm long and fitted in groups of three every 15 m on the central conductor of a distribution line with vaulted structures, were shown to be of little use under test conditions.

Lastly, the fitting of black neoprene strips 35 cm long, attached to the side conductors by plastic fasteners on a line with portal structures and no ground cable, proved to be effective as an anti-collision marker for practically all birds present in the area of the tested line, except for Great Bustards, a species for which the problem of power line collisions has yet to be solved.

## CONCLUSIONS

This research has allowed a specific methodology to be put into practice for identifying the impact of overhead powerlines on birdlife, with sound sampling methods and a thoroughgoing scientific treatment of field data.

As a result much more is now known about bird deaths, about the scope of the problem, the species and bird groups most liable to be affected, and the influence of various factors on mortality rates; furthermore a range of corrective measures has been tested to find out which are most effective. The results obtained and solutions proposed therefore represent a fundamental reference point for any future work in this area.

The limitation of the study to protected sites of natural interest and the concentration on species under threat, protected or in danger of extinction in no way lessens the general validity of the results. On the contrary they may be applied to any area and to all bird species.

The work carried out is of enormous interest to public bodies involved in the conservation of Spain's natural heritage, conservation bodies, the electricity companies themselves and installation companies of privately operate powerlines. All may use the conclusions herein presented to help in their search for reliable, low-cost solutions to lessen or eliminate the impact of powerlines on birds, whilst also finding solutions to the problems associated with running and maintaining the grid. Many actions previously undertaken to protect birdlife from the impact of overhead powerlines were not based on prior studies that would guarantee the effectiveness of the corrective measures at hand. This uncertainty led to continuous delays in their adoption. The effectiveness of commercial anti-electrocution devices was highly dubious, while most corrective solutions, such as burying lines underground or the use of braided cables, were complex and costly.

The solutions offered by this research are simpler, more effective and cheaper and may be fitted to a great number of structures in little time using low-cost materials. The protection prototypes tried out have been tried and tested for use on existing lines and may be applied across the board, whatever the structure or voltage involved.

The electricity companies promoting this research put into practice the preliminary conclusions of the study even before it ended. Their overhead lines are now among the safest in Spain, in marked contrast to the great danger still posed by privately run distribution lines. The solution of this latter problem calls for the intervention of the Public Administration, which should demand the use of safe designs in new lines and encourage the modification of those already working. For this undertaking the "Manual for Evaluating Risks and Solutions", written when the research work was over, is the basic reference document, showing the most suitable solutions for each installation type.

One of the most important conclusions to come out of the project was the demonstration that most accidents happen with a limited number of structures (electrocution) and spans (collision). The information now available means that the potentially most dangerous structures can be identified and the most suitable modifications be proposed, complete with sound estimates of the resulting fall in mortality.

The project results also offer the possibility of making reliable predictions of bird mortality caused by overhead powerlines in a specific site of natural interest, once the make up of the birdlife and the type of habitat and powerlines involved are known. It also allows accident hot-spots to be pinpointed and the most suitable solutions to be proposed. Until now such tasks called for years of dedication and a sizeable investment, while today it is possible to do so at a low cost and with a minimum number of samples.

## ACKNOWLEDGEMENTS

This communication is a contribution to the Project "Analysis of the environmental impacts of powerlines on birds living in protected areas". This Project was financed by funds of the PIE, a research programme of Spanish electricity companies.

The following organisations, technical experts and researchers took part in this Project: Compañía Sevillana de Electricidad, Mr. J. Casas and Mr. J. Muñoz; Iberdrola, Mr. G. Gazo, Mr. J.L. Larrea, Mr. J.R. Urcelay and Mr. J. Goitia; Red Eléctrica de España, Mr. J. Roig and Mr. V. Navazo; Consejo Superior de Investigaciones Científicas (High Scientific Research Council), Dr. M. Ferrer; Environment Agencies of Andalucía and Extremadura, Ms. R. Pintos and Mr. A. Sánchez; ICONA (Nature Conservation Institute), Mr. R. Cadenas; A.T. Clave, Mr. A. Lazo, Ms. G. Janss and Mr. J. Sánchez; and O.C.I.D.E., Mr. J. Gortázar.

## REFERENCES

Alonso, J.C., J.A. Alonso, and R. Muñoz-Pulido. 1994. Mitigation of bird collisions with transmission lines through groundwire marking. Biological Conservation, 67: 129–134.

Ansell, A.R. and W.E. Smith. 1980. Raptor protection activities of the Idaho Power Company. In: Workshop on Raptors and Energy Developments. R.P. Howard and J.F. Gore, eds. pp. 56–70

Avian Power Line Interaction Committee (APLIC). 1994. Mitigating bird collisions with powerlines: The state of the art in 1994. Edison Electric Institute. Washington, D.C.

Avian Power Line Interaction Committee (APLIC). 1996. Suggested practices for raptor protection on powerlines: The state of the art in 1996. Edison Electric Institute/Raptor Research Foundation. Washington, D.C.

Beaulaurier, D.L. 1981. Mitigation of bird collisions with transmission lines. Bonneville Power Administration, U.S. Dept. of Energy, Portland, Oregon.

Benson, P.C. 1980. A study of large raptor electrocution and power pole utilization in six western states. In: Workshop on Raptors and Energy Developments. R.P. Howard and J.F. Gore, eds. pp. 34–40

Benson, P.C. 1981. Large raptor electrocution and power pole utilization: A study in six western states. Ph.D. Dissertation. Brigham Young University, Provo, Utah. 98 pp.

Cadenas, R. and M. Mañez. 1988. Tendidos eléctricos: Actuaciones para minimizar el impacto ambiental sobre la avifauna. Vida Silvestre, 63: 59–46.

EPRI. 1993. Avian Interactions with Utility Structures. Proceedings of the EPRI International Workshop, Miami, Florida, 13–16 September 1992. Electric Power Research Institute.

Faanes, C.A. 1987. Bird behaviour and mortality in relation to powerlines in prairie habitat. U.S. Fish and Wildlife Service General Technology Report, 7: 24 pp.

Ferrer, M. and C. De le Court. 1988. Les Aigles Imperiaux espagnols menacés d'electrocution. L'Homme et L'Oiseau, 4: 231–236.

Ferrer, M. and F. Hiraldo. 1992. Man-induced sex-biased mortality in the Spanish Imperial Eagle. Biological Conservation, 60: 12–17.

Ferrer, M., M. De La Riva and J. Castroviejo. 1986. Impacto de los tendidos eléctricos en las poblaciones de rapaces de Doñana. Comunicación a la V Conferencia Internacional de Rapaces Mediterráneas. Evora, Portugal.

Ferrer, M., M. De La Riva and J. Castroviejo. 1991. Electrocution of raptors on powerlines in Southern Spain. Journal of Fields Ornithology, 62: 54–69.

Fiedler, G. and A. Wissner. 1980. Overhead electric lines as a mortal danger to Storks. Ecol. Birds, 2: 59–109.

Fiedler, G. and A. Wissner. 1986. Freileitungen als tödliche Gefahr für Weisstörche (*Ciconia ciconia*). Beih. Veröff. Naturschutz Landschaftspflege Bad. Württ., 43: 257–270.

Garzon, 1977. Birds of prey in Spain, the present situation. World Conference on Birds of Prey, Report of Proceeding, (R.D. Chancellor, de.). International Council for Bird Preservation. pp. 159–170.

Haas, D. 1980. Gefährdung unserer Grossvögel durch Stromeschlag eine Dokumentation (Endangerment of our large birds by electrocution. Ökol. Vägel, 2 (Sonderh.): 7–57.

Heijnis, R. 1980. Bird mortality from collision with conductors for maximum tension. Ecol. Birds, 2: 111–129.

Ledger, J.A., J.C.A. Hobbs, and T.V. Smith. 1993. Avian interactions with utility structures: Southern African experiences. Avian Interactions With Utility Structures. Proceedings of a Workshop, Miami, Florida, 13–16 September 1992. Electric Power Research Institute.

Lee, J.M. 1980. Raptors and the BPA transmission system. In: Workshop on Raptors and Energy Developments. Proceedings of a Workshop held in Boise, Idaho, 25–26 January 1980. R.P. Howard and J.F. Gore, eds. pp. 41–55

McNeil, R., J.R. Rodríguez, and G. Quellet. 1985. Bird mortality at a power transmission line in northeastern Venezuela. Biological Conservation, 31: 153–165.

Morkill, A.E. and S.H. Anderson. 1991. Effectiveness of marking powerlines to reduce sandhill crane collisions. Wildlife Society Bulletin, 19 (4): 442–449.

Navazo, V. and J. Roig. 1993. Las líneas de transporte de energía eléctrica y la avifauna. Tecnoambiente, 36: 79–84.

Negro, J.J. 1987. Adaptación de los tendidos eléctricos al entorno. Monografías de Alytes número 1.

Negro, J.J., M. Ferrer, C. Santos, and S. Regidor. 1988. Eficacia de dos métodos para prevenir electrocuciones de aves en líneas eléctricas de distribución. Ardeola, 36: 201–206.

Olendorff, R.R. 1981. Suggested practices for raptor protection on powerlines: The state of the art 1981. Raptor Research Report, number 4.

Olendorff, R.R. 1993. Eagle electrocution. In: Avian Interactions with Utility Structures. Proceedings of a Workshop, Miami, Florida, 13–16 September 1992. Electric Power Research Institute.

Peacock, E. 1980. Powerline electrocution of raptors. In: Workshop on Raptors and Energy Developments. Proceedings of a Workshop, Boise, Idaho, 25–26 January 1980. R.P. Howard and J.F. Gore, eds. pp. 2–5.

Regidor, S., C. Santos, M. Ferrer, and J.J. Negro. 1988. Experimentos con modificaciones para postes eléctricos en el Parque Nacional de Doñana. Ecología, 2: 251–256.

Roig, J. 1991. Accidents connus avec des ouvrages électriques en Espagne. Actes du Colloque International les Cigognes d'Europe. Metz, France, 3, 4 et 5 Juin.

Smith and Murphy 1972. Unusual causes of raptor mortality. Raptor Research, 6: 4–5.

Van Daele, L.J. 1980. Osprey and powerpoles in Idaho. In: Workshop on Raptors and Energy Developments. Proceedings of a Workshop, Boise, Idaho, 25–26 January 1980. R.P. Howard and J.F. Gore, eds. pp. 104–122.

## *BIOGRAPHICAL SKETCHES*

### *Jorge Roig-Solés*

*Head of the Environmental Service, Red Eléctrica de España, S.A., P° del Conde de los Gaitanes, 177, 28190 Alcobendas-Madrid, Spain*

Jorge Roig-Solés is a Mining Engineer at the Polytechnic University of Madrid. He holds a Diploma in Environmental Engineering from the University of Strathclyde (Glasgow).

### *Víctor Navazo-López*

*Environmental Service, Red Eléctrica de España, S.A., P° del Conde de los Gaitanes, 177, 28109 Alcobendas-Madrid, Spain*

Víctor Navazo-López is a Biologist at the University of Madrid and Master in Ecoaudit and Environmental Managers' Planning at the University of Málaga.

# Mitigation of Impacts to Timber Rattlesnakes (*Crotalus horridus horridus*) During Replacement of a Natural Gas Transmission Line in Southeastern New York

**Roderick Soper and Karl Schoeberl**

Timber rattlesnakes are listed as a threatened species in the State of New York and as such are afforded legal protection under State Law. Central Hudson Gas and Electric Corporation replaced approximately 9.7 km (6 miles) of a 25.4 cm (10-inch) natural gas pipeline in southeastern, New York. Preliminary wildlife surveys revealed that approximately 0.5 km (0.3 mile) of the right-of-way was located within an area used by timber rattlesnakes as basking habitat. Concern was expressed by regulatory agencies over possible impacts to rattlesnake populations in this area. A mitigation plan was developed in consultation with the involved agencies that outlined a procedure to capture and remove any timber rattlesnakes encountered during all phases of construction, and right-of-way restoration procedures to restore rattlesnake habitat within the delineated basking area. During construction, three timber rattlesnakes were captured and removed from the right-of-way. Restoration procedures involved the careful replacement of boulders and smaller rocks that were utilized as basking areas and escape cover for the rattlesnake. This mitigation plan documented that impacts to a threatened species can be successfully mitigated while concurrently improving wildlife habitat.

*Keywords*: Timber rattlesnake, pipeline, habitat, mitigation plan, regulatory review, utility, construction, New York State Public Service Commission

## INTRODUCTION

The timber rattlesnake (*Crotalus horridus horridus*) (Fig. 1) is found throughout the eastern half of the United States covering 30 states from eastern Kansas, Oklahoma and Texas to limited areas across New York and New England (Brown 1993, Conant and Collins 1991). Distribution of the snake has dwindled within New York historically since the arrival of settlers to North America (Stechert 1982). Current estimations of population size, based on surveys of denning locations and basking habitat, have indicated that timber rattlesnake populations have been steadily decreasing throughout New York State and New England (Brown 1992, Stechert 1992). These surveys indicate an approximate 60 % decrease of rattlesnake populations within New York and northern New Jersey since 1900 (Stechert 1992).

Reductions in population size and habitat loss have been attributed to a variety of factors. Changing land use patterns (i.e., increased residential, commercial, and industrial development) within timber rattlesnake habitat has increased the interactions between the rattlesnake and humans leading to a decrease of timber rattlesnake numbers and occasionally denning sites throughout their range. The loss of denning locations is critical as the timber rattlesnake depends on these dens to hibernate and survive the cold winters of the northeast. The exposure of the timber rattlesnake has also lead to an increase of illegal snake hunting which has further decreased timber rattlesnake populations. Consequently, New York has classified the timber rattlesnake as a threatened species which mandates legal protection of the snake and its associated habitat. Neighboring New England states such as New Hampshire, Connecticut, Vermont, and Massachusetts have

Fig. 1. Dark phase gravid female timber rattlesnake with a typical blotched pattern.

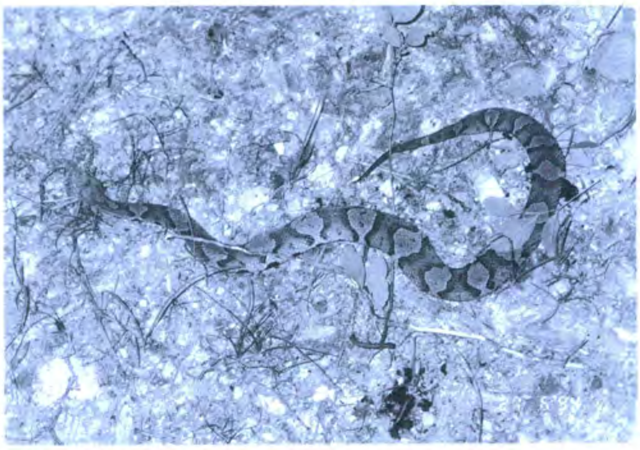


Fig. 2. Copperhead that was located along the right-of-way.

listed the timber rattlesnake as endangered, while Maine and Rhode Island classify the snake as extirpated (Breisch 1992).

In April 1994, Central Hudson Gas and Electric Corporation (Central Hudson) filed an application with the New York State Public Service Commission (PSC) pursuant to Article VII of the New York State Public Service Law and the implementing regulations at 16 NYCRR Part 85, for the reconstruction of 10.1 km (6.3 miles) of an existing 25.4 cm (10 inches) diameter natural gas transmission line. In New York State, any fuel gas transmission line which extends one thousand feet or more, and transports gas at 125 psig or more, is regulated by the PSC and must obtain a Certificate of Environmental Compatibility and Public Need before construction can commence. During the Certification review it was determined that this line, located in Orange County in southeastern New York, traversed through potential basking habitat for the timber rattlesnake. That determination, coupled with the location of a nearby den, increased the probability that rattlesnakes could be utilizing this area for thermo-regulation, foraging, and escape cover. Consequently, the pipeline right-of-way was surveyed for the presence of rattlesnakes and assessed for the presence of suitable rattlesnake habitat so that measures could be developed to mitigate impacts associated with the construction.

The survey confirmed that approximately 0.5 km (0.3 miles) of the right-of-way did have high potential to be used by timber rattlesnakes for basking habitat. This area of the right-of-way was identified only as an "environmentally sensitive area" so as to maintain anonymity of the area as suitable rattlesnake habitat, and to reduce the potential for unwanted intrusions (i.e., poachers). The survey did not locate any timber rattlesnakes, but one copperhead (*Agkistrodon contortrix*) (Fig. 2) was located indicating that individual rattlesnakes from the nearby den may be using the area as copperheads and timber rattlesnakes will often use the same denning locations in the northeastern United States.

The survey also found that the techniques used when the old pipeline was originally constructed in 1950, improved rattlesnake habitat quality by leaving an abundance of boulders piled over the ditch. These boulders offered excellent habitat for rattlesnake basking and/or shelter. Ongoing maintenance has kept the right-of-way free of tall trees, and nearly 100% sunlight conditions exist throughout the area (Fig. 3). This was of particular significance as the surrounding area consists of a somewhat closed canopy oak forest that does not allow much sunlight to reach the ground.

During permitting of the project, there was concern that disturbance of the rocks over the original pipeline ditch could potentially expose rattlesnakes to direct damage from heavy rocks or equipment, and could leave them more susceptible to predation (human, animal, or avian). Additionally, there was concern that if the timber rattlesnakes were located by construction personnel, they might be killed. As a result of these concerns, a mitigation plan was developed in order to help avoid some of the potential impacts to the timber rattlesnake along the pipeline corridor.

Fig. 3. Pipeline right-of-way showing placement of large rocks left during construction of the pipeline in 1950.

## MITIGATION TECHNIQUES

### Mitigation measures

In consultation with the PSC and New York State Department of Environmental Conservation (DEC), a mitigation plan was developed to address concerns and risks for the timber rattlesnake where potential impacts were possible. The plan was comprised of both written and verbal agreements which called for the following measures to be taken:

- a person qualified in the handling of venomous snakes (given the title 'snake monitor') would be on site any time construction equipment traversed, or construction activities were conducted, within the area delineated as potential snake habitat;
- the snake monitor would conduct daily pre-construction walkovers prior to any construction activities within the delineated rattlesnake area;
- signs were to be posted within the right-of-way at the ingress and egress of the area so all construction personnel would know where mitigation requirements were in effect;
- all construction activities and personnel be confined to the right-of-way;
- all construction personnel would be educated about timber rattlesnakes in the project area and informed what to do in case of a timber rattlesnake encounter;
- large rocks that had previously served as backfill for the pipeline would be returned to the right-of-way in a manner that would be beneficial for the timber rattlesnake.

These mitigation measures were followed throughout the construction and restoration phases of the project and were conducted under the authority of an endangered species permit issued to the snake monitor by DEC.

### Implementation of mitigation measures

The plan was implemented through the environmental inspector for Central Hudson who acted as a coordinator between the construction personnel and the snake monitor. The inspector insured that the snake monitor was on site before construction activities took place within the delineated rattlesnake habitat. The inspector and snake monitor also instructed construction personnel about the timber rattlesnake, informing them of its legally protected status and advising them not to harass or kill any snakes found. Personnel were informed that the timber rattlesnake is not aggressive by nature and will, if not antagonized or startled, avoid conflicts with humans. Additionally, the construction personnel were informed that if a timber rattlesnake was encountered they were to suspend all construction activities until the snake monitor had removed the snake or had determined that there was no longer a threat to the animal from construction.

While on site, the snake monitor stayed by all construction equipment as the various pipeline re-construction tasks were completed. Special attention was paid to the removal of the pipe overburden as this area had the highest likelihood for an encounter due to the presence of large boulders that would have to be moved in order to remove the old pipe. In the event a snake was observed, the equipment operator and the snake monitor were to work closely together so the operator could hold the boulder in place while the snake monitor removed the snake from under the rock and place it into a sealed plastic container. A state licensed herpetologist would then be called to place the captured rattlesnake in a nearby area with suitable habitat to decrease the chance of the snake's return to the right-of-way. If the snake appeared to be injured, the monitor would contact a wildlife rehabilitator so the snake could receive proper veterinary care.

## RESULTS

Three timber rattlesnakes were encountered during the replacement pipeline project. The first snake was a 104 cm (41 inch) pre-shed male that was found under a rock as it was moved during grading of the right-of-way. When the snake was discovered great care was taken by the operator to hold the boulder sheltering the snake in place until the snake could be removed. When the snake was secured in a large plastic container, a state licensed herpetologist was notified as soon as possible to remove the snake from the right-of-way. During the process of moving the snake it was observed that the snake had contusions and abrasions that occurred when its shelter rock was moved. The snake was turned over to a wildlife rehabilitator for treatment and observation. The snake later died, presumably from the observed injuries. A necropsy of the animal revealed that the snake had incurred lethal internal injuries.

A second snake was observed by the equipment operator during the refueling of a backhoe within the delineated rattlesnake habitat. The snake was located between the backhoe and a previously strung piece of pipe. The operator notified the snake monitor who promptly captured the snake. The snake was estimated to be 101–114 cm (40–45 inches) in length and was in excellent condition. Working with the herpetologist, the snake monitor had previously located several suitable release sites in the vicinity of the project area prior to the capture of the second snake. The second captured snake was subsequently released to one of those locations.

Locating these release sites eliminated the need for the herpetologist to come on site which decreased the amount of time the snake was held in captivity and reduced the likelihood of snake/human interaction. Release sites were chosen that would place the captured snake closer to the den location, but far enough away from the right-of-way to reduce the chance the snake would return. In all cases the snakes that were captured and returned to the wild were released within the same den population to insure survivability of the captured snake.

The last snake observed was found during the trenching operation and was located under a large boulder that was removed adjacent to the pipe trench. Again, the operator held the boulder in place while the snake monitor removed the snake from under the rock. The snake was estimated to be approximately 64 cm (25 inches) in length and was also in excellent condition. It was captured, placed in a large plastic container, and placed in a shaded location until there was a break in the trenching operations. The snake was then released soon after its capture at one of the prescribed off site locations.

Once construction was complete in the snake mitigation area, right-of-way restoration measures were initiated. This primarily consisted of careful replacement of boulders, left previously by the construction of the original pipeline, back to their pre-existing position (or as close as possible). During the grading operations to prepare the right-of-way for construction, the snake monitor worked closely with the equipment operators to save those boulders that were best suited for timber rattlesnake basking for return to the right-of-way. Modern day restrictions and Central Hudson safety polices would not allow rocks to be placed immediately over the ditch in their original location. For that reason the rocks were placed within the right-of-way, but slightly off the centerline of the replaced pipeline trench. Rocks were placed in such a manner that flat surfaced boulders obtained the maximum amount of sunlight possible while still allowing snakes to shade under the same rock. This was accomplished as much as possible within the entire basking area, and with the additional clearing conducted for construction, improved the habitat for timber rattlesnakes.

## SUMMARY

Mitigation measures used to lessen impact to the timber rattlesnake can be done in a variety of ways depending on the project and the potential impact to the snake. If it is practicable, one of the most successful ways to mitigate impact is to coordinate construction activities outside the period of time the snake will be most active. This window is approximately from mid-October through mid-April in New York state, but can occasionally be expanded or contracted depending on the distance of the project from existing dens, and the availability of rattlesnake basking and foraging habitat (Stechert 1995, 1996). This allows a project to be completed while the timber rattlesnake is within the den and far decreases the chance the snake will be directly harmed from construction activities. For this project that was not practical due to timing constraints and gas delivery schedules.

However, with the implementation of this mitigation plan, the utility company was able to complete the project in a timely and cost-effective manner while still maintaining protection for the resource. The loss of the one timber rattlesnake is, unavoidably, part of the impact that this resource did incur, but the majority of the timber rattlesnakes encountered were successfully removed from the right-of-way unharmed. Ironically, the primary reason that the timber rattlesnakes utilized the basking area was due to the maintained right-of-way, and the placement of the rocks when the pipeline was originally constructed in 1950. Through continued right-of-way vegetation management, environmental sensitivity, and common sense, this prime rattlesnake habitat will continue to exist well into the future. Additionally, with continued diligence in timber rattlesnake habitat conservation, the timber rattlesnake can continue to use the site in much the same way it did prior to construction of the replacement pipeline.

## ACKNOWLEDGEMENTS

The authors would like to thank Central Hudson for the use of the information found within this publication. A word of thanks goes also to Randy Stechert for his review and comment on this paper and his unselfish and unparalleled dedication to the conservation of the timber rattlesnake and other reptilian species.

## REFERENCES

Breisch, A.R. 1992. Summary of state/provincial regulations concerning the timber rattlesnake. In: Conservation of the Timber Rattlesnake in the Northeast. T.F. Tyning, ed. Massachusetts Audubon Society, Lincoln, Massachusetts, pp. 7–8.

Brown, W.S. 1993. Biology, status, and management, of the timber rattlesnake (*Crotalus horridus*): A guide for conservation. J.T. Collins, ed., Herpetological Circular No. 22.

Brown, W.S. 1992. Biology and conservation of the timber rattlesnake. In: Conservation of the Timber Rattlesnake in the Northeast. T.F. Tyning, ed. Massachusetts Audubon Society, Lincoln, Massachusetts, pp. 9–13.

Conant, R. and J.T. Collins. 1991. A field guide to reptiles and amphibians of eastern and central North America, 3rd edition. Houghton Mifflin Co., Boston, Massachusetts.

Stechert, R. 1995. Letter report to Alvin Breisch, Senior Wildlife Biologist with the Endangered Species Unit, Wildlife Resources Center, Delmar, New York, dated July 1, 1995.

Stechert, R. 1992. Distribution and populations status of *Crotalus horridus* in New York and northern New Jersey. In: Conservation of the Timber Rattlesnake in the Northeast. T.F. Tyning, ed. Massachusetts Audubon Society, Lincoln, Massachusetts, p. 1.

Stechert, R. 1982. Historical depletion of timber rattlesnake colonies in New York State. Bulletin of the New York Herpetological Society, 17: 23–24.

## *BIOGRAPHICAL SKETCHES*

*Roderick Soper*

*Phenix Environmental, Incorporated, 30 Broadway, Suite 207, Kingston, New York 12401, USA*

Mr. Roderick Soper works with Phenix Environmental as Manager of Environmental Services for their Kingston, New York office. He holds a Bachelor of Science Degree in Wildlife Ecology from Oklahoma State University and a Masters of Science Degree in Wildlife and Fisheries Ecology also from Oklahoma State University.

*Karl Schoeberl*

*Environmental Affairs Division, Central Hudson Gas and Electric Corporation, 284 South Avenue, Poughkeepsie, New York 12601, USA*

Mr. Schoeberl works for Central Hudson Gas and Electric Corporation as an Environmental Specialist. He holds a Bachelor of Science degree in Natural Resources from Cornell University.

# Conservation of the Gopher Tortoise and Associated Species During Construction of the Florida Gas Transmission Company Phase III Expansion Project

**Edward E. Wester and Joe W. Kolb**

In 1994–95 Florida Gas Transmission Company constructed a 1,312-km (815-mile) natural gas pipeline from Louisiana to southern Florida. Preliminary surveys of the Phase III Expansion Project right-of-way indicated that the gopher tortoise, *Gopherus polyphemus*, occurred along much of the route and was especially abundant along those portions of the project route in peninsular Florida. The gopher tortoise is federally protected as a threatened species on those portions of the Phase III right-of-way in eastern Louisiana, south Mississippi, and southwestern Alabama. The gopher tortoise is also protected by state law in Louisiana, Mississippi, Alabama and Florida. Prior to initiation of construction activities, multiple teams of biologists, working simultaneously along the entire Phase III route, conducted intensive gopher tortoise burrow surveys, inspected burrows with remote video systems, collapsed unoccupied burrows, and ultimately trapped or excavated gopher tortoises occurring in burrows within the construction corridor. Gopher tortoises and any other vertebrate commensal organisms (such as the threatened eastern indigo snake) were temporarily displaced into burrows located adjacent to the construction corridor or into suitable adjacent habitat. The Phase III right-of-way was routinely resurveyed for new gopher tortoise burrows immediately before construction and all open trenches were inspected daily for tortoises or any other trapped wildlife. At project completion, 5,934 burrows had been cleared from the construction corridor and 2,524 gopher tortoises had been displaced, making this one of the largest single-species relocation efforts ever undertaken. Over 450 other vertebrate commensal organisms (including 40 species of frogs, lizards, snakes, mammals and birds) were also removed from burrows and displaced. Recaptures of marked tortoises and radio-telemetry studies indicated that displaced tortoises remained in the immediate vicinity throughout construction. Following revegetation, gopher tortoises have now reoccupied many areas of the Phase III right-of-way. Florida Gas Transmission Company's program of temporary displacement proved successful and had a significantly lesser impact on the gopher tortoise and substantially lower cost than would have a program of off-site relocation.

*Keywords*: Gopher tortoise, natural gas pipeline, right-of-way, conservation, wildlife, threatened species, relocation

## INTRODUCTION

Maintained rights-of-way often provide suitable habitat for numerous species of wildlife. In the southeastern U.S. one species in particular, the gopher tortoise (*Gopherus polyphemus*), can often be found in relative abundance on utility corridors. The gopher tortoise is a large, terrestrial turtle that prefers open, sunny habitats with a well-developed herbaceous ground flora (Auffenberg and Franz 1982, Diemer 1986, Landers 1980). As such, gopher tortoises are frequently attracted to maintained pipeline, powerline and highway rights-of-way, especially in areas where adjacent habitats have been degraded by adverse land-use practices.

The gopher tortoise occurs in suitable Coastal Plain habitats from extreme eastern Louisiana through the southern portions of Mississippi, Alabama and Georgia into extreme southern South Carolina and southward throughout much of Florida (Auffenberg and Franz 1978). Gopher tortoises generally occur in colonial aggregations on well-drained sandy or gravelly soils of xeric, upland, open forests and savannahs (Auffenberg and Franz 1982, Carr 1952, Mount 1975). The species is probably best known for the extensive burrows it digs. Adult burrows are generally 5–7 m in length and 2–3 m deep but may extend up to 14 m in length (Ernst and Barbour 1972). The burrows provide the gopher tortoise with refuge from the physiologically demanding environment in which the species occurs. Gopher tortoise burrows also provide refuge for as many as 400 different species of invertebrates, frogs, lizards, snakes, mammals and even birds, many of which are believed to be obligate commensal species (Franz 1986, Mount 1975, Young and Goff 1939). As such, the gopher tortoise is often referred to as a "keystone species" in upland habitats of the southeastern U.S. Coastal Plain (Eisenberg 1983).

As have many other species, the gopher tortoise has declined substantially throughout its range (Auffenberg and Franz 1982, Lohoefener and Lohmeier 1984). Adverse forestry practices, agriculture, urbanization and human predation are considered to be the primary factors responsible for this decline (Auffenberg and Franz 1982, Diemer 1986, Pulliam 1987). Gopher tortoises are now protected as a threatened species, under the Endangered Species Act of 1973 (as amended), in Louisiana, Mississippi and southwestern Alabama ("western population"). Gopher tortoises are also protected under state conservation laws or regulations throughout the species' range.

In 1994–1995, Florida Gas Transmission Co. (FGT), an Enron/Sonat affiliate, constructed 1,312 km (815 miles) of large diameter natural gas pipeline from Louisiana to south Florida. Construction of the Phase III Expansion Project occurred largely within FGT's existing pipeline right-of-way and within other existing utility rights-of-way. All but a small portion of the project route was within the range of the gopher tortoise, and gopher tortoises were known to be present along much of FGT's existing right-of-way as well as other rights-of-way used for construction. Given the size and length of the pipeline rerouting was not feasible. As such, FGT was required to develop and implement an extensive gopher tortoise conservation program in conjunction with its Phase III Expansion Project.

Throughout the species' range, gopher tortoises threatened by construction activities are typically relocated, often substantial distances, away from the area of potential impact. However, such relocations are often considered unsuccessful in that most relocated gopher tortoises disperse from the relocation site to unknown locations and fates after release (Burke 1989, Diemer 1984, Diemer et al. 1989). Moreover, the potential impacts to the genetic and social integrity of the local populations from which gopher tortoises are relocated, as well as on the local populations into which they might be introduced, are unknown. FGT considered off-site relocation but the potential for adverse impacts to the gopher tortoise conjoined with the high costs of implementing an off-site relocation plan over such an extensive project necessitated development of a different approach to conservation of gopher tortoises likely to be impacted by the Phase III Expansion Project.

Unlike most construction projects, pipeline construction does not result in a permanent adverse modification of gopher tortoise habitat. Impacts are temporary and are associated primarily with the actual construction phase of a project. Following construction, revegetation and routine maintenance, pipeline rights-of-way typically provide suitable habitat for gopher tortoises, as evidenced by the abundance of gopher tortoises present on many such rights-of-way throughout the southeastern U.S. Given that the post-construction Phase III right-of-way would quickly again become suitable for gopher tortoises, FGT developed and implemented a conservation plan in which gopher tortoises (and commensal species) occurring in burrows within the construction corridor were only temporarily displaced into nearby, adjacent habitats unimpacted by pipeline construction.

## METHODS

### Preconstruction

Because of the scope of the Phase III Expansion Project, permitting of FGT's gopher tortoise conservation plan required extensive interaction with three U.S. Fish and Wildlife Service field offices, conservation departments in Louisiana, Mississippi, Alabama and Florida, two National Forests and the Federal Energy Regulatory Commission. In consultation with these agencies, FGT developed its plan of temporary displacement of gopher tortoises from the Phase III construction corridor.

Preliminary gopher tortoise burrow surveys were conducted along the Phase III right-of-way in 1992 and 1993. Because gopher tortoises frequently dig new burrows, the construction corridor was again resurveyed for burrows beginning in early February 1994, immediately prior to the initiation of displacement work. During these resurveys, all gopher tortoise burrows identified were examined with remote video systems that allow viewing of the entire length of the gopher tortoise burrows. All gopher tortoise burrows within the construction corridor that were conclusively determined to be unoccupied by a gopher tortoise or vertebrate commensal were collapsed. Subadult and hatchling burrows that were too small to examine and any burrows for which conclusive occupancy determinations could not be made were considered to be occupied and left undisturbed.

Capture and displacement of gopher tortoises from the Phase III construction corridor began in mid-February 1994 in southern Florida, where the gopher tortoise may be active throughout the year, and in late March/early April 1994 in northern Florida and southern Alabama, Mississippi and Louisiana, where gopher tortoises are generally inactive during the winter. The vast majority of gopher tortoises were displaced between late March and early June 1994. Gopher tortoises were trapped, excavated from their burrows or, occasionally, captured by hand at their burrow entrances. Gopher tortoises were trapped using pit-fall traps buried in front of the entrance of a burrow or using wire mesh live traps. All traps were checked twice daily, in the late morning and late afternoon. Following capture, all burrows were reinspected with a remote video system to insure that additional tortoises were not present and the burrows were then collapsed.

Gopher tortoises were excavated from their burrows either with hand-shovels or backhoes. Backhoes were used most extensively in peninsular Florida where the greatest densities of gopher tortoises occurred and where construction was not occurring adjacent to an existing pipeline. At times, as many as eight backhoes were in use simultaneously within a 1–2 km portion of the project route. Metal plates were welded across the teeth of backhoe buckets to facilitate a slow, progressive burrow excavation in which the operator could easily see the extent of his impact. During excavation, whether by hand or backhoe, a small, flexible tube was progressively inserted as far into each burrow as possible to insure that the burrow path was not obscured with loose dirt and potentially lost. Measurements indicated on the tube also allowed excavation efforts to stop just prior to reaching a gopher tortoise, thus reducing the chances of injury. All burrow excavations were backfilled following removal of the resident gopher tortoise.

All gopher tortoises captured were photographed (dorsal, ventral, anterior), measured (mass, plastral length, carapace length, bridge width), sexed (if mature), aged (if annuli discernable) and permanently marked. Marking was accomplished by drilling small holes in a specific combination of marginal scutes using a standard numbering scheme (Cagle 1944). To minimize the risk of potential disease transmission among displaced gopher tortoises, all captured tortoises were handled with disposable latex gloves or biologists washed their hands following handling of each gopher tortoise. Additionally, all remote video cameras, traps, shovels, backhoe buckets, burrow tubes, measuring calipers, etc. were disinfected with a dilute chlorox or alcohol solution after each use.

Immediately following capture and data collection, gopher tortoises removed from burrows within the construction corridor were released into inactive/abandoned gopher tortoise burrows located in unimpacted portions of FGT's existing right-of-way, into inactive/abandoned burrows located in suitable habitats adjacent to the construction corridor or directly into suitable adjacent habitats. Gopher tortoises were typically displaced less than 100 m from their original burrow and no gopher tortoises were displaced into burrows separated by an unsuitable barrier (e.g., road, creek, wetland) from their original capture location.

Approximately 193 km (120 miles) of the Phase III route passes through the range of the threatened "western population" of the gopher tortoise. Gopher tortoises in this portion of the species' range receive the greatest level of legal protection and, therefore, were the focus of FGT's most intensive conservation efforts. Several modifications to FGT's basic conservation plan were made for this portion of the project. Gopher tortoises within the construction corridor were either trapped using pit-fall traps or wire live-traps or they were excavated by hand from their burrows. No backhoes were used to excavate burrows on this portion of the Phase III route. In general, unoccupied burrows located adjacent to the construction corridor into which displaced gopher tortoises could be released were limited in number and often not available. Therefore, most displaced tortoises were released into starter burrows, dug to approximately one meter in length, in the adjacent, unimpacted portions of FGT's existing right-of-way. Existing inactive or abandoned burrows and starter burrows were surrounded by a temporary enclosure approximately eight meters in diameter. Temporary enclosures were constructed of 35 cm high aluminum sheeting buried approximately 10 cm into the ground. A single displaced gopher tortoise was held in each temporary enclosure for three weeks, after which the enclosures were removed. The enclosures were inspected daily throughout the confinement period. The intent of the temporary enclosures was to encourage displaced gopher tortoises to utilize and lengthen the starter burrows and to reduce the chances that they would attempt to return to the construction corridor and reoccupy their collapsed burrows or excavate new burrows.

To ensure that construction of the Phase III Expansion Project did not adversely impact protected or sensitive burrow commensal species such as the threatened eastern indigo snake (*Drymarchon corais couperi*), dusky gopher frog (*Rana capito sevosa*) or Florida mouse (*Podomys floridanus*), FGT also committed to protect all vertebrate burrow commensals. Any burrow in which a vertebrate commensal was observed with a remote video system was either left undisturbed and the commensal organism allowed to disperse on its own or the burrow was excavated. Captured vertebrate commensals were released into gopher tortoise burrows in adjacent habitats unimpacted by pipeline construction or directly into adjacent habitats.

Construction of the Phase III Expansion Project occurred at multiple locations along the project route simultaneously. Therefore, it was necessary for FGT to implement its gopher tortoise conservation plan simultaneously at multiple locations spread over virtually the entire 1,312 km (815-mile) construction corridor. During periods of peak activity, 41 biologists were directly involved in gopher tortoise conservation efforts along the Phase III route. An additional 15–20 operators and associated personnel were also involved during periods of extensive backhoe use.

To minimize the potential for adverse impacts to gopher tortoises and burrow commensals in the immediate vicinity of construction activities, FGT incorporated discussions and a video summary of its gopher tortoise conservation plan into preconstruction environmental training for project construction personnel. Project biologists also interacted with construction personnel throughout construction to ensure continued understanding and compliance with FGT's gopher tortoise conservation plan and to ensure that changes in construction plans and schedules were incorporated into ongoing gopher tortoise conservation efforts.

### Construction

During project planning, there was significant and justified concern that displaced gopher tortoises would attempt to return to the construction corridor and reoccupy their collapsed burrows or excavate new burrows. There was also concern that gopher tortoises from adjacent habitats might excavate new burrows between the time that burrows were initially cleared from the construction corridor and the beginning of construction. Fencing of both sides of the construction corridor in areas with gopher tortoises was considered but ultimately rejected because of the tremendous costs associated with erecting, inspecting and maintaining hundreds of miles of tortoise-proof fences. Instead, FGT biologists continuously conducted resurveys of the construction corridor immediately ahead of each land-disturbing construction activity such as clearing, grading, trenching, etc. All new burrows excavated by gopher tortoises within the construction corridor were treated as previously described.

Along many parts of the project route, numerous gopher tortoise burrows occurred immediately adjacent to the construction corridor in unimpacted portions of FGT's existing right-of-way and in suitable adjacent habitats. To protect such burrows from impacts associated with inadvertent off right-of-way activities, all burrows located immediately adjacent to the Phase III construction corridor were identified as off-limits areas using protective flagging and/or barricade fencing. Adjacent burrows were monitored daily by project biologists throughout periods of active construction to insure continued protection and compliance with FGT's conservation plan.

Project biologists inspected all open trenches daily for gopher tortoises and any other wildlife that may have become trapped in the trench. Spoil piles were also examined regularly for evidence of gopher tortoise burrows. Project biologists were onsite at all times in all major construction areas throughout construction of the Phase III Expansion Project. Construction of the Phase III Expansion Project was completed in the areas of greatest gopher tortoise densities by September 1994.

### Postconstruction

To help assess the success of its program of temporary displacement of gopher tortoises from the Phase III construction corridor, FGT conducted a radiotelemetry study of the movements of displaced gopher tortoises and conducted resurveys of the Phase III right-of-way approximately six months following construction. FGT's radiotelemetry study was conducted within the threatened range in Louisiana and Mississippi and is discussed in detail in Wester and Kolb (in prep). Postconstruction gopher tortoise burrow surveys were conducted during 25–30 May 1995, along two five-mile portions of the Phase III construction corridor in each of eight Florida counties with the greatest gopher tortoise densities.

To assess the potential long-term impacts of operation and maintenance of the Phase III pipeline within the range of the threatened "western population" of the gopher tortoise, FGT is also required to conduct a study of those potential long-term impacts. That study is currently ongoing.

## RESULTS

At the conclusion of FGT's gopher tortoise conservation efforts, 5,934 gopher tortoise burrows were cleared from the Phase III construction corridor. A total of 1,725 burrows (29.1%) were found to be unoccupied as a result of examinations with remote video systems and were collapsed, 2,791 burrows (47.0%) were excavated with backhoes, 693 burrows (11.7%) were cleared by trapping the resident gopher tortoises, 637 burrows (10.7%) were excavated by hand and 88 burrows (1.5%) were cleared by hand capture of the resident tortoise at the burrow entrance. A total of 2,524 gopher tortoises were temporarily displaced from burrows located within the Phase III construction corridor. Within the threatened range of the gopher tortoise in Louisiana, Mississippi and southwestern Alabama 87 gopher tortoises were displaced, four gopher tortoises were displaced in the range of the non-threatened population in Alabama and 2,433 gopher tortoises were temporarily displaced from the Phase III construction corridor in Florida. Table 1 summarizes, by state and county/parish, the numbers of gopher tortoises displaced and burrows cleared from the construction corridor during FGT's gopher tortoise conservation efforts.

Active/inactive burrow-to-tortoise correction factors are often used to estimate abundance of gopher tortoises. A total of 2,496 (98.9%) of the gopher tortoises displaced from the construction corridor were captured from burrows subjectively classified as active or inactive prior to examination with a remote video system. However, 28 (1.1%) gopher tortoises were displaced from burrows subjectively classified as abandoned. Burrow-to-tortoise correction factors varied over the project route but overall, 49% of the burrows subjectively classified as active or inactive were

**Table 1. Summary of gopher tortoises displaced and burrows cleared from the FGT Phase III construction corridor and burrow-to-tortoise correction factors**

| County/ parish | Males | Females | Subadults[2] | Total tortoises | Active/inactive burrows | Correction factor | Abandoned burrows |
|---|---|---|---|---|---|---|---|
| LOUISIANA | | | | | | | |
| Washington[1] | 11 | 15 | 1 | 27 | 72 | 0.38 | 9 |
| MISSISSIPPI | | | | | | | |
| Forrest[1] | 0 | 0 | 0 | 0 | 9 | 0.00 | 1 |
| George[1] | 1 | 2 | 0 | 3 | 6 | 0.50 | 2 |
| Pearl River[1] | 1 | 1 | 0 | 2 | 3 | 0.67 | 1 |
| Perry[1] | 16 | 11 | 9 | 36 | 57 | 0.63 | 6 |
| Stone[1] | 1 | 1 | 0 | 2 | 2 | 1.00 | 0 |
| Subtotal | 19 | 15 | 9 | 43 | 77 | 0.56 | 10 |
| ALABAMA | | | | | | | |
| Baldwin | 2 | 1 | 0 | 3 | 6 | 0.50 | 1 |
| Escambia | 0 | 1 | 0 | 1 | 1 | 1.00 | 2 |
| Mobile[1] | 10 | 6 | 1 | 17 | 48 | 0.35 | 3 |
| Subtotal | 12 | 8 | 1 | 21 | 55 | 0.38 | 6 |
| FLORIDA | | | | | | | |
| Brevard | 4 | 5 | 1 | 10 | 18 | 0.56 | 0 |
| Calhoun | 9 | 2 | 2 | 13 | 24 | 0.54 | 7 |
| Citrus | 124 | 149 | 298 | 571 | 1098 | 0.52 | 212 |
| Gadsden | 1 | 4 | 1 | 6 | 18 | 0.33 | 1 |
| Gilchrist | 33 | 35 | 61 | 129 | 321 | 0.40 | 54 |
| Hernando | 104 | 98 | 383 | 585 | 1267 | 0.46 | 152 |
| Hillsborough | 10 | 10 | 26 | 46 | 86 | 0.53 | 29 |
| Holmes | 1 | 0 | 0 | 1 | 3 | 0.33 | 1 |
| Jefferson | 8 | 2 | 8 | 18 | 33 | 0.55 | 12 |
| Lafayette | 46 | 45 | 37 | 128 | 246 | 0.52 | 55 |
| Leon | 36 | 18 | 26 | 80 | 183 | 0.44 | 49 |
| Levy | 48 | 61 | 80 | 189 | 343 | 0.55 | 48 |
| Liberty | 5 | 1 | 4 | 10 | 28 | 0.36 | 3 |
| Madison | 3 | 0 | 0 | 3 | 5 | 0.60 | 0 |
| Okaloosa | 3 | 4 | 4 | 11 | 18 | 0.61 | 7 |
| Osceola | 24 | 16 | 10 | 50 | 80 | 0.63 | 6 |
| Pasco | 70 | 86 | 163 | 319 | 642 | 0.50 | 53 |
| Polk | 3 | 5 | 9 | 17 | 35 | 0.49 | 7 |
| Santa Rosa | 6 | 0 | 2 | 8 | 16 | 0.50 | 4 |
| St Lucie | 2 | 1 | 0 | 3 | 11 | 0.27 | 0 |
| Suwannee | 72 | 60 | 44 | 176 | 328 | 0.54 | 43 |
| Taylor | 8 | 8 | 6 | 22 | 38 | 0.58 | 4 |
| Walton | 4 | 6 | 7 | 17 | 41 | 0.41 | 13 |
| Washington | 10 | 7 | 4 | 21 | 40 | 0.53 | 23 |
| Subtotal | 634 | 623 | 1176 | 2433 | 4922 | 0.49 | 783 |
| Total | 676 | 661 | 1187 | 2524 | 5126 | 0.49 | 808 |

[1]Range of the federally threatened "western population" of the gopher tortoise.
[2] Includes juveniles and hatchlings.

occupied by a gopher tortoise (Table 1). The overall active/inactive burrow occupation rate was substantially less than the 61.4% correction factor typically used to estimate gopher tortoise abundance (Auffenberg and Franz 1982).

In general, displaced gopher tortoises did not attempt to reoccupy burrows in the construction corridor from which they were originally displaced. However, in areas of high gopher tortoise density both displaced tortoises and tortoises from adjacent habitats frequently excavated new burrows in the construction corridor between the time the corridor was initially cleared of burrows and initiation of construction activities. A total of 128 (5.1%) previously displaced gopher tortoises were recaptured from new burrows excavated within the construction corridor. Following initial grading operations, excavation of new burrows within the construction corridor was minimal.

Displaced gopher tortoises as well as tortoises from adjacent habitats also occasionally became trapped in open trenches. A total of 26 gopher tortoises were removed from trenches during construction. In a few cases, gopher tortoises trapped in trenches attempted to excavate burrows within the trenches, making the tortoises difficult to identify. Gopher tortoises also occasionally attempted to excavate burrows in spoil piles adjacent to trenches. Gopher tortoises becoming trapped in open trenches and digging burrows in spoil piles were most problematic in areas where habitat adjacent to the construction corridor was poor in quality.

Use of starter burrows and temporary penning of displaced gopher tortoises occurred only within the range of the threatened "western population" of the gopher tortoise. Most displaced gopher tortoises did not attempt to lengthen their starter burrows. All displaced gopher tortoises dispersed from their starter burrows within one to two days following removal of the enclosures. Radiotelemetric monitoring of movements of displaced gopher tortoises (Wester and Kolb, in prep) indicated that tortoises dispersed to existing burrows in habitats adjacent to the construction corridor and to other starter burrows located in the unimpacted portions of FGT's existing right-of-way. By late summer 1994, most starter burrows were in use by displaced gopher tortoises or tortoises from adjacent habitats and had been lengthened substantially.

Injury and mortality of gopher tortoises during implementation of FGT's conservation plan was minimal. Fifteen (0.59%) gopher tortoises received minor injuries during backhoe excavation efforts. Ten (0.40%) gopher tortoises were killed or suffered injuries of sufficient severity to warrant euthanasia during backhoe excavation efforts. Nine (0.36%) gopher tortoise burrows collapsed during excavation and the resident tortoises could not be found; and, although the excavations were left open, no evidence of a gopher tortoise digging out were observed. Two (0.08%) gopher tortoises within the threatened range also died, presumably as a result of their being temporarily penned. One gopher tortoise was apparently poached from an enclosure and one tortoise apparently died from heat stress while pacing the periphery of the enclosure. Overall, 21 (0.83%) gopher tortoises are thought to have died during displacement efforts. There was no evidence of any gopher tortoise injury or mortality during the construction phase of the project.

Postconstruction gopher tortoise burrow surveys along 129 km (80 miles) of the Phase III route in eight Florida counties identified a total of 76 new burrows. If the burrow-to-tortoise correction factors determined by FGT for each county are used to estimate the numbers of gopher tortoises present in these new burrows, the return rate of gopher tortoises to the Phase III construction corridor (new burrows × county correction factor / number of tortoises initially displaced) ranges from 0 to 16.6% (Table 2).

**Table 2. New gopher tortoise burrows and estimated rates of return of gopher tortoises to the construction corridor approximately six months following construction of the FGT Phase III Expansion Project**

| County | FGT Milepost | Tortoises displaced | Burrows cleared | New burrows | Correction factor | % Est. return |
|---|---|---|---|---|---|---|
| Citrus | 83.2–88.2 | 155 | 380 | 8 | 0.52 | 2.68 |
| | 94.8–99.8 | 144 | 293 | 2 | 0.52 | 0.72 |
| Gilchrist | 14.5–19.5 | 43 | 142 | 1 | 0.40 | 0.93 |
| | 25.4–30.4 | 32 | 81 | 0 | 0.40 | 0.00 |
| Hernando | 106.9–111.9 | 209 | 468 | 1 | 0.46 | 0.22 |
| | 113.0–118.0 | 184 | 490 | 2 | 0.46 | 0.50 |
| Lafayette | 491.3–496.3 | 42 | 116 | 10 | 0.52 | 12.38 |
| | 496.9–501.9 | 66 | 137 | 21 | 0.52 | 16.55 |
| Leon | 419.0–424.0 | 26 | 75 | 1 | 0.44 | 1.69 |
| | 425.9–430.9 | 15 | 35 | 1 | 0.44 | 2.93 |
| Levy | 31.1–36.1 | 53 | 102 | 4 | 0.55 | 4.15 |
| | 66.5–71.5 | 93 | 169 | 2 | 0.55 | 1.18 |
| Pasco | 121.0–126.0 | 183 | 438 | 4 | 0.50 | 1.09 |
| | 126.0–131.0 | 76 | 136 | 0 | 0.50 | 0.00 |
| Suwannee | 501.9–506.9 | 90 | 172 | 19 | 0.54 | 11.40 |
| | 0.0–5.0 | 35 | 85 | 0 | 0.54 | 0.00 |
| Overall | | 1446 | 3319 | 76 | 0.49 | 2.58 |

**Table 3. Summary of vertebrate commensals displaced from gopher tortoise burrows within the FGT Phase III construction corridor**

| | |
|---|---|
| Amphibians | |
| Tiger salamander | 2 |
| Other salamander (no ID) | 1 |
| Spadefoot toad | 6 |
| Greenhouse frog | 67 |
| Southern toad | 59 |
| Oak toad | 3 |
| Narrowmouth toad | 12 |
| Florida gopher frog | 84 |
| Other frog (no ID) | 18 |
| Birds | |
| Burrowing owl | 4 |
| Mammals | |
| Armadillo | 8 |
| Opossum | 1 |
| Cotton rat | 2 |
| Mouse (no ID) | 42 |
| Vole (no ID) | 1 |
| Pocket gopher | 1 |
| Eastern cottontail | 5 |
| Striped skunk | 9 |
| Gray fox | litter |
| Bobcat | 1 |
| Reptiles | |
| Anole (no ID) | 3 |
| Six-lined racerunner | 10 |
| Skink (no ID) | 3 |
| Slender glass lizard | 1 |
| Florida worm lizard | 13 |
| Eastern garter snake | 1 |
| Eastern ribbon snake | 1 |
| Eastern hognose snake | 1 |
| Black racer | 3 |
| Eastern coachwhip | 20 |
| Corn snake | 1 |
| Florida pine snake | 1 |
| Eastern indigo snake | 6 |
| Short-tailed snake | 1 |
| Crowned snake | 1 |
| Scarlet kingsnake | 2 |
| East diamondback rattlesnake | 2 |
| Dusky pigmy rattlesnake | 6 |
| Eastern coral snake | 1 |
| Cooter (no ID) | 1 |

Numerous vertebrate burrow commensals were observed in gopher tortoise burrows with remote video systems. In many cases it was possible to leave burrows with vertebrate commensals open until the commensals dispersed from the burrows. Unfortunately, this often meant that positive species identifications could not be made and that numbers of individuals could not always be determined. Similarly, many small, quick commensals such as lizards, mice, etc. escaped from gopher tortoise burrows during excavation and could not always be positively identified or counted. Overall, at least 450 vertebrate burrow commensals, of at least 41 different species, were displaced from burrows within the Phase III construction corridor (Table 3).

## DISCUSSION AND CONCLUSIONS

FGT's Phase III gopher tortoise conservation program was the largest gopher tortoise conservation effort ever undertaken. The results of FGT's efforts clearly indicate that with proper planning and implementation, natural gas pipeline construction can occur through areas occupied by gopher tortoises with only minimal adverse impacts. Temporary displacement of gopher tortoises resulted in a significantly lesser impact to the gopher tortoise and a significantly more cost-effective conservation effort than would have a program of off-site relocation. While temporary displacement of gopher tortoises may not be feasible for most types of construction projects, it should be considered the preferred alternative for pipeline and other utility rights-of-way that will recover and subsequently remain suitable for gopher tortoises following construction.

The results of FGT's radiotelemetry study of movements of displaced gopher tortoises (Wester and Kolb, in prep), recaptures of previously displaced tortoises within the construction corridor and return of tortoises to the Phase III construction corridor all indicate that gopher tortoises displaced prior to construction remained in the immediate vicinity of their capture. Limited trapping of gopher tortoises on and immediately adjacent to the Phase III construction corridor (conducted in Leon Co., FL in association with a long-term study by FGT) approximately two years after construction also indicates that displaced tortoises have likely not dispersed long distances from original locations. Of 23 gopher tortoises captured over 18 km (11 miles) of the Phase III route in fall 1996, six (26%) were tortoises previously displaced from the construction corridor.

The value of holding displaced gopher tortoises in temporary enclosures within the species' threatened range was questionable and likely resulted in an unnecessary loss of two gopher tortoises. Given that gopher tortoises along other portions of the Phase III route that were not held in temporary enclosures apparently remained in the immediate vicinity and could be easily recaptured if they excavated new burrows in the construction corridor, it is recommended that temporary enclosures not be used in future projects of this nature. Starter burrows were eventually used and lengthened by gopher tortoises after the temporary enclosures were removed and may be of value on future projects in areas where there are only minimal numbers of nearby inactive/abandoned burrows into which displaced tortoises can be released.

FGT's Phase III Expansion Project demonstrates that removal of gopher tortoises from a construction corridor can be accomplished safely and efficiently. The greatest problem encountered during the project was the need to repeatedly resurvey and clear new burrows from the construction corridor between the time of initial clearing of burrows and the ultimate initiation of construction activities. Personnel responsible for displacing gopher tortoises were charged with clearing gopher tortoise burrows from the construction corridor as quickly as possible to avoid potentially impacting construction progress. However, overall, gopher tortoise displacement activities were accomplished very efficiently; but, because of inevitable delays and schedule changes, construction efforts often did not reach areas cleared of burrows as planned. The repeated efforts required prior to construction in many areas added to the costs of implementing FGT's gopher tortoise conservation plan and increased the numbers of gopher tortoises that were temporarily impacted by capture and handling activities. In future projects, every effort should be made to limit the time between gopher tortoise displacement and initiation of construction activities in a given area.

## REFERENCES


Auffenberg, W. and R. Franz. 1978. *Gopherus polyphemus*. In Catalog of American amphibians and reptiles. Society for the Study of Amphibians and Reptiles, pp. 215.1–215.2.

Auffenberg, W. and R. Franz. 1982. The status and distribution of the gopher tortoise (*Gopherus polyphemus*). In: North American Tortoises: Conservation and Ecology. R.B. Bury, ed. U.S. Department of Interior, Fish and Wildlife Service, Wildlife Research Report 12. pp. 95–126.

Burke, R.L. 1989. Florida gopher tortoise relocation: overview and case study. Biological Conservation, 48: 295–309.

Cagle, F.R. 1944. Home range, homing behavior, and migration in turtles. Miscellaneous Publications, Museum of Zoology, University of Michigan, 61: 1–34.

Carr, A. 1952. Handbook of Turtles. Cornell University Press, Ithaca, New York. 542 pp.

Diemer, J. 1984. Tortoise relocation in Florida: Solution or problem? Proceedings of the Desert Tortoise Council Annual Meeting, 1984.

Diemer, J. 1986. The ecology and management of the gopher tortoise in the southeastern United States. Herpetologica, 42: 125–133.

Diemer, J., D.R. Jackson, J.L. Landers, J.N. Layne and D.A. Wood., eds. 1989. Gopher Tortoise Relocation Symposium Proceedings. Nongame Wildlife Program Technical Report Number 5. Florida Game and Freshwater Fish Commission, Tallahassee, Florida. 109 pp.

Eisenberg, J. 1983. The gopher tortoise as a keystone species. In: Proceedings of the Fourth Annual Meeting of the Gopher Tortoise Council, Gainesville, Florida. pp. 1–4.

Ernst, C. and R. Barbour. 1972. Turtles of the United States. University Press of Kentucky, Lexington, Kentucky. 347 pp.

Franz, R. 1986. *Gopherus polyphemus* (gopher tortoise) burrow commensals. Herpetological Review, 17: 64.

Landers, J.L. 1980. Recent research on the gopher tortoise and its implications. In: Proceedings of the First Annual Meeting of the Gopher Tortoise Council, Gainesville, Florida. pp. 8–14.

Lohoefener, R. and L. Lohmeier. 1984. The status of *Gopherus polyphemus* (Testudines, Testudinidae) west of the Tombigbee and Mobile rivers. Unpublished report submitted to U. S. Fish and Wildlife Service. 104 pp.

Mount, R.H. 1975. The reptiles and amphibians of Alabama. Alabama Agricultural Experiment Station. 345 pp.

Pulliam, J. 1987. Endangered and threatened wildlife and plants; determination of threatened status for the gopher tortoise (*Gopherus polyphemus*). Federal Register, 52: 25376–25380.

Young, F.N. and C.C. Goff. 1939. An annotated list of the arthropods found in the burrows of the Florida gopher tortoise, *Gopherus polyphemus* (Daudin). Florida Entomologist, 22: 53–62.


## *BIOGRAPHICAL SKETCHES*


***Edward E. Wester***

*President, Southern Ecosystems Research, 6485 Lee Road 54, Auburn, AL 36830, USA*


Edward E. Wester has a B.S. degree in Biology and a M.S. degree in Zoology. His work is focused primarily on endangered species conservation. He has worked extensively with gopher tortoises throughout the species' range. Prior to his work at SER, he taught biology, ecology and evolutionary biology at Auburn University.


***Joe W. Kolb***

*Senior Environmental Specialist, Enron Operations Corp., P.O. Box 1188, Houston, TX 77251-1188, USA*


Joe W. Kolb has B.S. and M.S. degrees in Biology from Southwest Texas State University. He spent 14 years with the predecessors of the Texas Natural Resource Conservation Commission. His seven years on the Enron Corp environmental affairs staff has included a wide range of environmental assignments, including a three year assignment with Florida Gas Transmission Company.

# Part VII
# Biodiversity

# Power Lines and Biodiversity in the Colombian Territory

**Esteban Alvarez Dávila**

This paper presents a conceptual framework of the effects of high-voltage energy transmission lines on the biotic component of Colombia's terrestrial ecosystems. The discussion is illustrated with cases of ISA's projects — the company in charge of the largest part of the National Interconnected System (NIS) in Colombia. During the design and construction of the lines, the main impacts are caused by the removal of vegetation along the corridor and by the opening of roads for the transportation of material and labor. Because of the high diversity, endemism patterns and ecological deterioration of the Andean region, the greatest impact occurs precisely there where the largest part of the NIS infrastructure is concentrated. Additionally, the cutting of vegetation sometimes produces the fragmentation of remnants of original habitats, increasing the impact because of the degradation process generated in the ecosystem. A description of the environmental management model developed by ISA for the prevention and handling of such impacts is presented, emphasizing the indispensability of an appropriate characterization of the biodiversity.

*Keywords*: Transmission line, rights-of-way, biodiversity, impact of high-voltage energy lines, environmental management, Colombia

## INTRODUCTION

Located in the intertropical zone in the northernmost part of South America, Colombia has a surface equal to 0.8% (approximately 1.2 million km$^2$) of the land of the world, but contains a number of flora and fauna species representing 10% of the total biodiversity of the planet (Hernández et al. 1992). This fact places Colombia among the twelve countries with the highest biodiversity in the world. At the same time it gives the country an instrument of great relevance for its development policies considering (a) the strategic importance that biodiversity is gaining worldwide (Folke, Mäler, and Perrings 1992; Wilson 1988) including recognition of its importance by such international financial entities such as the World Bank (Dinerstein, Olson, and Graham 1995), and (b) that nearly 50% of its national territory is still covered by forest vegetation (Andrade 1992; Cantera 1993).

Nevertheless, the reports on deforestation rates in Colombia, reaching 0.6 million ha per year, give an immediate idea of the critical status of biodiversity, and of the speed at which biological extinction might be moving. It is estimated that only 5% of the North Andean forests are left (Henderson, Churchill, and Luteyn 1991), and the fact that they are located in one of the least explored and most biologically important regions of the world (van Velzen 1991) makes the situation more serious. Other Colombian regions of equal biological importance such as Chocó and the Amazon are far from the critical status of the Andean region, but require prompt attention as well. A recent study in Latin America and the Caribbean (LAC) (Dinerstein, Olson, Graham et al. 1995) shows that most of the Colombian territory comprises areas with the highest degrees of priority, according to regional and world levels, for developing biodiversity conservation strategies.

Interconexión Eléctrica S.A. (ISA) is a government company in charge of planning, designing, building, operating, and maintaining the high voltage power lines (PTL) in Colombia. Today, the network comprises more than 14,000 km of lines (with an area of direct influence of 40,000 ha) which traverse regions of very high biodiversity with precarious conservation status. ISA started the environmental management in its line projects in 1985 (ISA 1994) making it the leader not only in Colombia but also in Latin America. However, the environmental management model has been constantly updated in accordance with the growing worldwide concern about environmental problems caused by development projects. Consequently, ISA has decided to implement an impact management policy appropriate to the new national and global scenario in which biodiversity is emphasized, with the support of a series of national regulatory laws. This paper presents a conceptual model of how ISA intends to mitigate the impacts caused by its projects on Colombian biodiversity.

## CONCEPTUAL FRAME

### General characteristics of the PTL system in Colombia

The Power Transmission Line network in Colombia has 14,471 km of high voltage lines (ISA 1994). The direct responsibility of ISA consists of 6,572 km of 230 and 500 kv power lines, twenty-two 230 kv substations, four 500 kv substations, and a 4,864 mv amperes (MVA) transformation capacity. The projects executed within the Expansion Plan until the year 2000 will increase the ISA network by 530 km of 500 kv lines and by 1,018 km of 230 kv lines. Transformation capacity will be augmented by 2400 MVA, and four 500 kv and 59 230 kv substation modules (ISA 1996). A scheme of the interconnected Colombian system is shown in Fig. 1, including the new projects of the Expansion Plan until the year 2000.

The construction of a power line requires the acquisition of the rights of way in a corridor approximately equal to the distance between the substations it is to connect, and of variable width depending on the power to be transmitted. The widths for the rights-of-way corridors used in Colombia for high voltage PTL are 20,

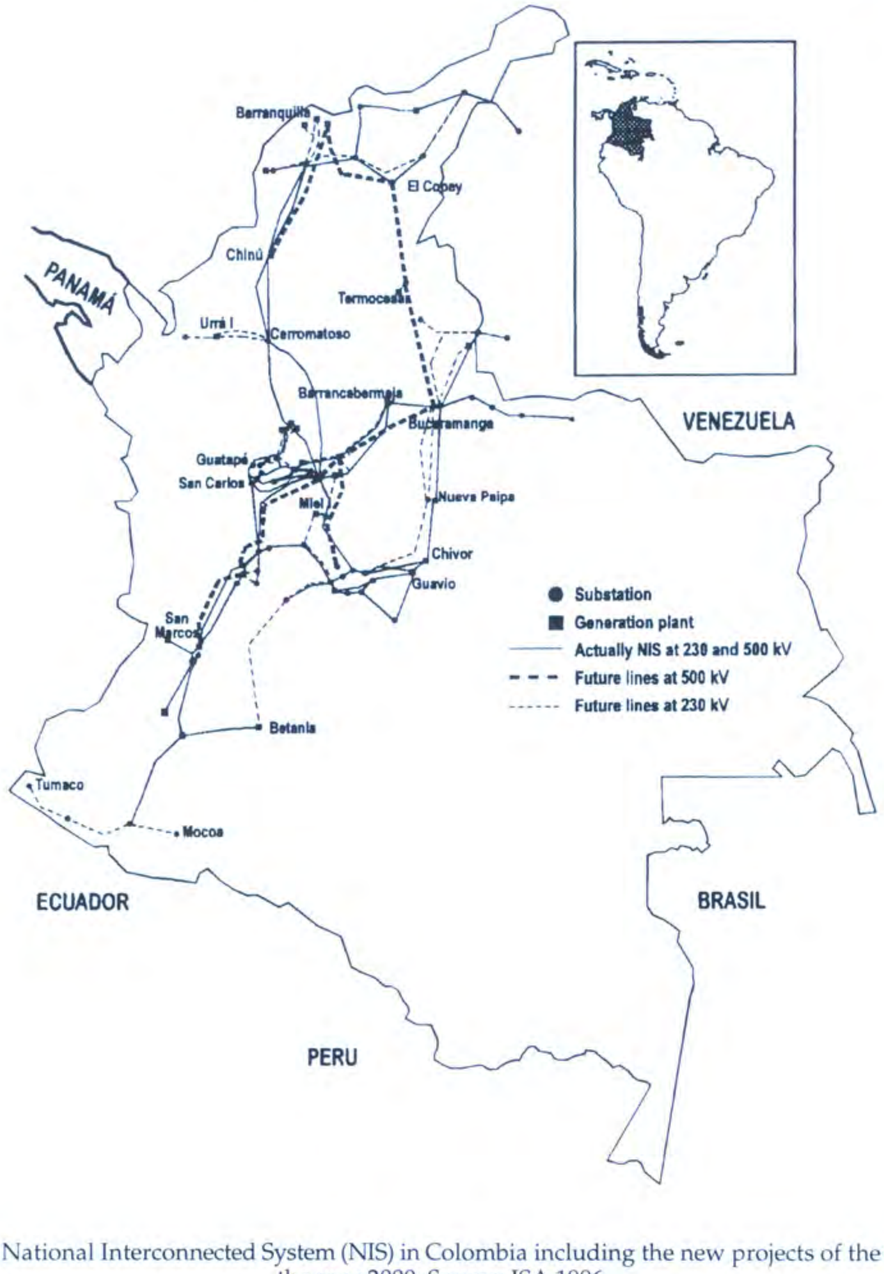



Fig. 1. Scheme of the National Interconnected System (NIS) in Colombia including the new projects of the Expansion Plan until the year 2000. Source: ISA 1996.

32 and 62 m for 115, 230, and 500 kv lines, respectively. As a result, the high voltage power system in Colombia must have the rights of way in an approximate area of 39,686 ha, throughout the country, but mainly in the Andean region and in the Atlantic coastal plain, where the main cities and major industrial centers are located.

### Colombian biodiversity and conservation status

Colombia holds nearly 10% of the world's biota including 19% of birds and 17% bats (Hernández et al. 1992). The flora of Colombia, Peru and Ecuador may represent at least one-sixth of the total flowering plants in the world (NRC 1992). Recent research studies have established that the different types of forest ecosystems still existing in Colombia contain the highest plant species richness in plots of known area in the world. For example, the report of the highest density of vascular plants with a diameter equal or greater than 2.5 cm in two 0.1 ha plots is in Chocó: 258 and 265 (Gentry 1993). For the Amazon 382 and 329 species of terrestrial vascular plants between 0.5 and 3.0 m high (Alvarez, Londoño, and Cogollo 1996) and greater than 0.5 m high (Duivenvoorden 1994), respectively, in 0.1 ha plots were recently reported. Additionally, Henderson, Churchill and Luteyn (1991) estimated a density of one species per $km^2$ for the north of the Andes as compared to one species for every 235 $km^2$ for the Amazon, generally considered to be the region with the highest plant diversity in the world.

Colombian land ecosystems include a wide spectrum of humidity and temperature gradients (Espinal and Montenegro 1963). Annual rainfall ranges from 0 to 10,000 mm and elevation is from sea level to almost 5,000 meters. A wide range of ecosystems is found along trophic gradients ranging from soils poor in nutrients to some of the most fertile in all the intertropical zone (IGAC 1995). To summarize, 22 of the 37 tropical biotic zones are represented in Colombia. Three are also in the subtropical region (Hernández 1992). This great diversity of environments and geologic position helps to explain the enormous biodiversity in the Colombian territory.

Dinerstein, Olson, Graham et al. (1995) have established a biological distinctiveness index for all the ecoregions of Latin America and the Caribbean, which shows the importance of biodiversity in Colombia (Fig. 2A). The ecoregions were classified into different categories of biological distinctiveness (global, regional, bioregional, and local) according to four fundamental criteria: (a) Species richness with emphasis on plant, mammal, bird, reptile, amphibian, and butterfly taxa; (b) endemisms based on these same taxa; (c) gamma and beta diversities and the complexity of endemism patterns, and (d) the occurrence of certain rare or unique ecological phenomena in terms of their structure and dynamic properties. Although all ecoregions are different in biological terms, particularly in terms of species, some Colombian ecoregions are so rich and complex that they stand out from the rest. More than 50% of the Colombian territory is classified as of global biological distinctiveness, due to the extraordinary levels reached (Fig. 2A). Thus, most of the country has a great richness of species, of endemisms, of diversity between ecosystems and regions, and of distinct ecological processes.

Besides species richness, there are other attributes in Colombian geography to be considered. Particularly in

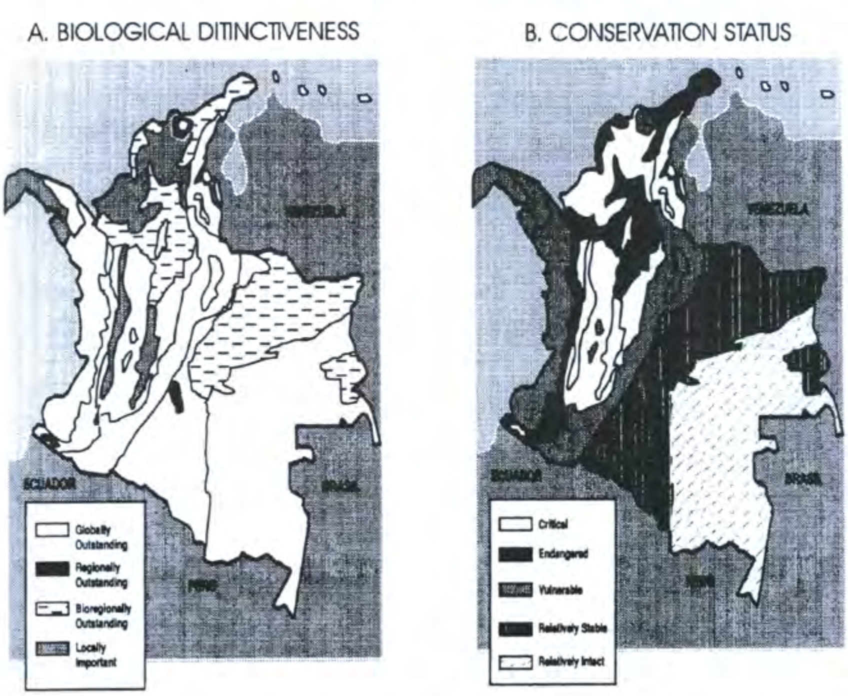



Fig. 2. General characteristics of biodiversity in Colombia, showing (A) the outstanding areas at different levels, and (B) the current conservation status. Conventions according to Dinerstein, Olson, and Graham (1995). See also text.

the Andes the combination of a complex topography and the climate, geology, and biogeographical history has contributed to the creation of an immense beta diversity (Gentry 1992; Hilty and Brown 1986; Terborgh and Winter 1983). Furthermore, despite their less complex environmental characteristics there is a high level of biotic endemism and of complex beta diversity patterns in both the Amazon and Chocó (Andrade 1995; Cuadros 1992; Duivenvoorden 1995; Gentry 1990; Gentry 1993; Londoño and Alvarez 1997; Rangel and Lowy 1993; Ruiz, Hernandez and Ardila 1993; Stiles 1993; Urrego 1994).

Colombia can be divided into three great regions based on its human occupation history, which constitute in a certain way a natural resources degradation gradient (Fig. 2B): (a) A region which includes the three mountain ranges with their inter-Andean valleys and the Atlantic coastal plain which conservation status is endangered or critical; (b) the piedmont of the eastern and western mountain ranges, including the Pacific coast corridor which conservation status is vulnerable; and (c) the Orinoquia and Amazon plains which conservation status is relatively stable or intact. The areas in shown in Fig. 2B suggest that nearly 50% of the biological diversity in Colombia falls at least under the vulnerable condition, and that at least 25% under the critical or endangered condition. According to the authors, in this 25% — which includes the majority of the Colombian Andes with its inter-Andean valleys and the Atlantic coastal plain — are the remaining natural habitats that hold the greatest biological diversity of the zone and that could completely disappear during the next 15 years.

### Impacts of the PTL on Biodiversity

The main effect on the biota of the different construction, operation, and maintenance activities of a PTL is that produced by fundamentally one factor: the necessity of cutting the vegetation present in all the areas under its "direct" influence. This activity causes the direct destruction of plants and the destruction of habitats for fauna. The excavations required for the establishment of towers and access roads cause the alteration of soils and the destabilization of access side slopes which increase the potential of the effect of cutting the vegetation. The accumulation of the effects caused along the line depend on the length of the corridor. For example, the total area affected in the construction of the San Carlos–San Marcos line corresponding to the Expansion Plan until the year 2000 (Fig. 1) includes ca. 2,560 ha, without the access.

The problems caused to the biota by the cutting of vegetation, the alteration of soils, and the destabilization of side slopes is aggravated by the fact that in many cases they cause the fragmentation of forest relicts, which triggers a series of subsequent ecosystem degradation processes. Fragmentation causes great changes both in the physical environment and in the biogeographical ambit (Saunders, Hobbs, and Margules 1991) because it produces a mosaic of remnant vegetation patches which in turn influence the biota, altering its composition, structure, and original function, depending on different variables (isolation time, distance from and connectivity with other fragments, and changes in the surrounding landscape). According to Solbrig (1992), the genetic and demographic consequences of fragmentation can be severe, and the natural patterns of spatial and temporal variation within the species influence the degree of the impact; habitat fragmentation has serious effects on the genetic diversity levels of a species, and such effects can in turn affect the characteristics of its life history and probability of extinction. Therefore, it is currently admitted that these consequences are critical for the different biodiversity components (Bierregaard, Lovejoy, Kapos, Santos, and Hutchings 1992; Murcia 1996; Kattan, Alvarez, and Giraldo 1994; Turner 1996). Unfortunately, concrete studies of the impact on the biota caused by the fragmentation by power lines are scarce, particularly for the tropical regions (Roselli and De la Zerda 1997). Besides, to the "natural" impacts fragmentation has on the biota we have to add those caused by the intensification of human activities (use of firewood, selective logging, hunting) that are facilitated by the opening of the access and corridors within the forest relicts, further degrading the ecosystem.

Even though there is information about the general effects caused by fragmentation, those caused by power lines, especially in Colombia, have distinct characteristics. The PTL net in Colombia works in the most densely populated areas, mainly in the Andean region and the Atlantic coastal plain, some of the areas considered of extreme priority for the development of conservation activities (Fig. 3) because of their distinct and critical biodiversity status. Due to their pre and post-Hispanic occupation history, the Andean and Atlantic coast regions in Colombia have become almost totally fragmented landscapes where very small areas of native vegetation surrounded by an agrarian matrix of land or other land uses can be found.

The areas of native vegetation still found in the Andes owe their existence to the fact that they are located in the highest and most inaccessible parts of the landscape of river basins. The paradox the environmental managers of the PTL net in Colombia face is that these places are precisely the most appropriate ones for line transit. The construction of towers and required access generally takes place in the highest points of the areas through which the line goes, affecting the forest fragments that still exist and that constitute the last refuge for a great variety of animal and plant species.

Conservation biology has traditionally focused on protecting great areas of original habitats located far from human activity. However, such an approach is questioned nowadays arguing that these areas can hardly


Fig. 3. Conservation priorities of the area of influence of the interconnected system in Colombia. Level I: highest priority at regional scale; Level II: high priority at regional scale; Level III: moderate priority at regional scale. Adapted from ISA (1996) and Dinerstein, Olson, and Graham (1995).

**Table 1. Expansion Plan projects for the PTL net until the year 2000 and Colombian ecoregions of high priority for conservation (source: Dinerstein, Olson, and Graham (1995)**

| Power Lines Projects | Ecoregion |
|---|---|
| Sochagota–Guatiguara | North Andean paramo and Magdalena Valley montane forests |
| Ocaña–Cesar | Eastern Mountain Range and relict forests alluvial plain of Magdalena Valley |
| Sabanalarga–Fundación | Dry and relict forests alluvial plain of Magdalena Valley |
| Guatapé–Jaguas | Relicts of premontane forests in the Magdalena Valley |
| San Carlos–San Marcos | Cauca Valley montane forests |
| Betania–Mirolindo | Magdalena Valley dry forests |
| La Sierra–Doña Juana | Wet and relict forests alluvial plain of the Magdalena Valley |

represent by themselves the biotic diversity of an extensive geographical area and that the persistence of small ecosystems fragments is fundamental and may be the only hope for the survival of a large number of species (Shafer 1995; Kattan and Alvarez 1996; Murcia 1995; Schelhas and Greenberg 1996). Many invertebrates, plants, fungi, and small vertebrates can be effectively conserved within small blocks of original habitats and, at the same time, these fragments can act as a bridge for the movement and dispersion of species between bigger fragments (Dinerstein, Olson, and Graham 1995). Their conservation is a valuable tool to preserve elements of species and original communities, particularly in regions distinguished by high levels of beta diversity, like the Colombian Andes.

Unless adequate measures are taken, PTL projects can have serious implications for biodiversity, given the characteristics of the Expansion Plan of PTL in Colombia and the danger caused by the alteration of the habitat relicts in critical zones for biodiversity conservation (Table 1). Lastly, it should be mentioned that fragmentation caused by power lines does not occur exclusively when vegetation needs to be cut through forest relicts. Even the crossing of the line along open zones such as grasslands, savannas, or wetlands causes a type of fragmentation because the lines themselves are a physical barrier for species of high mobility (mainly birds) causing collision danger (Roselli and De la Zerda 1997).

## BIODIVERSITY STUDIES IN ISA PROJECTS

### The environmental management model of PTL projects in ISA

The study and characterization of the impacts caused by power lines in Colombia is relatively recent. Environmental management of these projects started in 1985 , but not until 1989 did impact studies begin to consider the socioeconomic component (ISA 1994). Since then, we have been making progress in the creation of a management model that integrates all the aspects comprising the human medium and the natural medium in their interaction with PTL (Angel, Carmona, and Villegas 1996). Today, we understand that biodiversity protection is an essential aspect of sustainable development, and that it requires an adequate understanding of social and ecological variables.

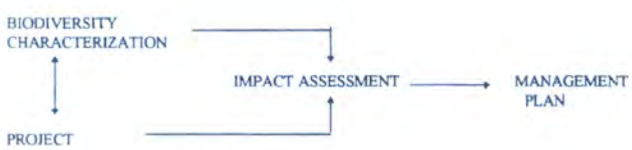
The environmental management of any development project should be made under the assumption that the best way of handling an impact is to avoid its occurrence. In the case of the impacts on biodiversity, the adoption of a series of strategies and appropriate programs for each of the technical phases of the projects is required. The articulation of the different phases of a power transmission project and the necessary strategies to prevent or handle to the maximum possible extent the impacts on the biotic medium are shown in Table 2. This approach has several analysis scales, from a regional level in the planning phase that includes hundreds of km$^2$, to a local or punctual level in the construction phase at a m$^2$ scale.

Impact assessment is a fundamental activity for environmental management in development projects.

**Table 2. Integration of the technical cycle and the management of impacts on biodiversity in Colombia (Interconexión Eléctrica S.A.)**

| Stage | Technical scope | Environmental scope |
|---|---|---|
| Planning | Determining necessary lines and substations to fulfill demand. | Analysis of restrictions: (a) biological reserves legally constituted by environmental authorities and those that are private areas or owned by non-governmental organizations; (b) wetland |
| Design | Route alternatives assessment. Selection of definite route. | (a) Assessment of biodiversity conservation status in the different route alternatives as one of the selection criteria. (b) Detailed assessment of the biotic impacts on the selected corridor. |
| Preconstruction | Processing of bids and contracts for equipment supply. Bids and contracts for civil works and supervision. | Creating and including an Environment Management Plan (EMP) regarding the impact on the biota in the bid specifications. |
| Construction | Definite restatement and construction of the project works. | Executing the EMP with prevention, mitigation, and correction measures for the impacts on biota. |
| Operation | Initiation of service and commercial operation. | Monitoring and execution of operation EMP. |
| Dismantling | Dismounting of structures and equipment. Final project evaluation. | EMP for dismantling. Follow-up to unsolved responsibilities. |

ISAs environmental group has tried to approach the problem based on the concept of analytical dimension, seeking strategies for the diagnosis, identification and evaluation of impacts and the formulation of management measures. The method intends to integrate the different topics and environmental components in the analysis, and defines "dimensions" as the set of physical, biotic, cultural, and political components of the environment and the interrelationships between them (Angel, Carmona, and Villegas 1996). The simplified impact assessment model is illustrated in the following diagram:




The perfecting of this general model has meant significant progress in impact assessment if we compare recent studies with those of only a few years ago. There is still a great weakness in important aspects, such as the low quality of the basic information used for quantifying the impacts on biodiversity. Nevertheless, it is important to highlight that the adequate characterization of diversity is a problem being discussed in both academic and scientific society (Magurran 1988), and not only for ISA studies or the electric sector in Colombia. In our case, though, the problem is so critical that ISA have no two consultants using similar methodologies, or even one implementing an acceptable methodology from a scientific perspective. Basic information in the majority of the cases is a list of species, often based on secondary information, or imprecise vegetation maps. Also, the lack of good basic information can be one of the reasons why the concept of analytical dimension is seldom implemented successfully in environmental impact studies, although it corresponds to the current approach to the biodiversity conservation problem throughout the world.

### Characterization of biodiversity

We are currently working on a standardized methodology for the characterization of biodiversity with scientific quality approved by the different institutions interested in the conservation and management of the environment in Colombia and the rest of the world. The first step is to combine the definition for biodiversity accepted at present (Halffter and Ezcurra 1992; Kikawa 1990; Noss 1990; Solbrig 1992) with the assessment techniques developed by landscape ecology (Jongman, ter Braak, and van Tongeren 1987) (which involve the physical dimension) and conservation biology (Dinerstein, Olson, and Graham 1995) (which involve the social dimension) , and adapt them to the use of modern tools such as remote sensors and geographical information systems (Cadena, Calinao, and Torres 1977). The conceptual model of biodiversity characterization, in which the above mentioned aspects are involved, is shown in Fig. 4.

The next step is to clearly define the scope and objectives of the characterization, as a detailed biodiversity inventory would be beyond the resources available for environmental management in the ISA projects. The same phases of the development of a power transmis-

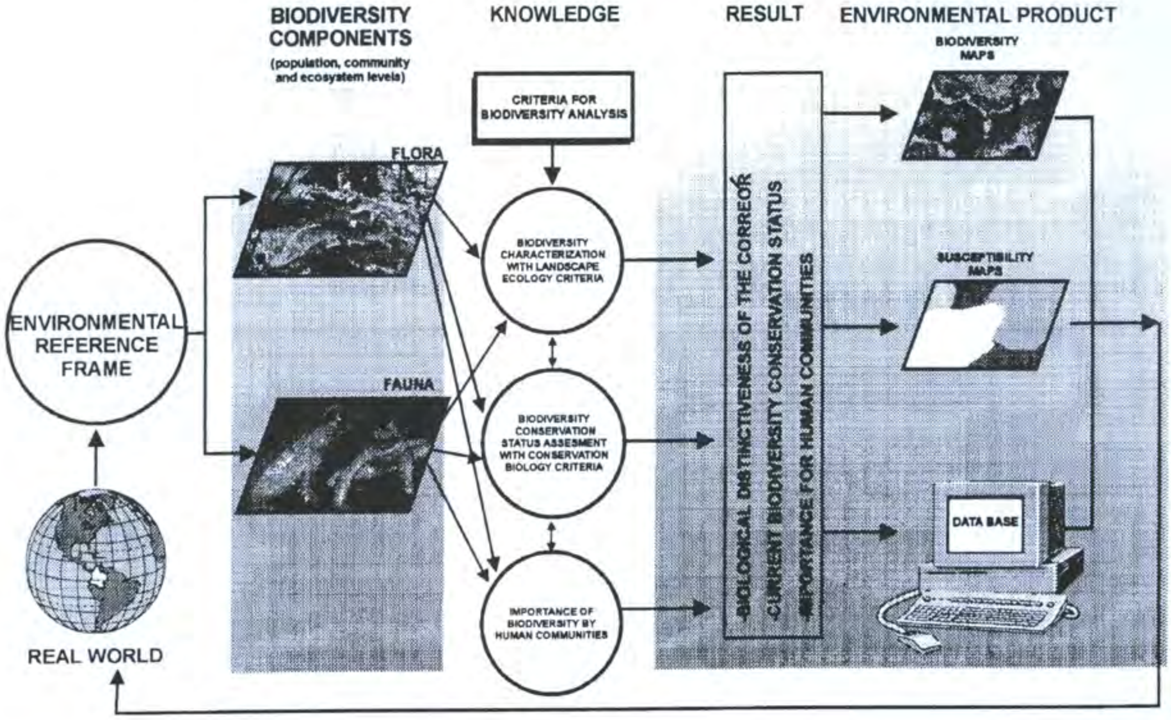



Fig. 4. Conceptual model for biodiversity evaluation for the ISA projects in Colombia.

sion project (Table 2) are a guide on how to proceed from "top to bottom" (Noss 1990), starting from a wide-scale inventory of the environmental restrictions in the planning stage, continuing with a lower-scale inventory of landscape patterns, vegetation, and habitat structure during the assessment of route alternatives (Dinerstein, Olson, and Graham 1995) and a fine-scale inventory of the selected route complemented with field sampling in plots for the study of areas previously selected according to their conservation status. To summarize, two levels of biodiversity characterization can be defined: the first, to a regional level, belongs to the so-called Environmental Analysis of Alternatives (EAA) and the second, to a local level, belongs to the Environmental Impact Assessment (Angel, Carmona, and Villegas 1996). The main difference is in their scope and detail. The first is undertaken at an early stage during the selection of project alternative, whereas the second is undertaken as a previous requirement for the initiation of the selected alternative (Table 3).

Field sampling is another issue in biodiversity studies, but the evidence that comparison of variables such as species richness must be done with data referring to equal units in size and shape, and identical minimal size limits and growing habits of the individuals and similar sampling efforts (UNESCO et al. 1982; Korning, Thomsen, and Ollgaard 1991; Magurran 1988) indicates that the methods more commonly reported should be followed (e.g., Gentry 1988 for vascular plants) along with the recent manuals for quick ecological assessments (Sobrevila and Bath 1992). Additionally, the Biodiversity Institute Alexander von Humboldt of the Colombian Ministry of the Environment is also working on the creation of a standardized methodology for biodiversity inventory, and we expect to be able to adapt it to our work.

**Table 3. Biodiversity characterization levels in the environmental management of electric energy transmission projects in ISA, Colombia**

| Alternative analysis (EAA) | | Impact assessment (EIA) | |
|---|---|---|---|
| 1. | Interpretation with remote sensors and GIS. Field inspections without inventories. Assessment of conservation status of the corridor. | 1. | Inventories in plots in places considered important. Refining of biodiversity conservation status. Selection of areas for further monitoring. |
| 2. | Emphasis on secondary information and expert opinions. | 2. | Emphasis on primary information and expert opinions. |
| 3. | Emphasis on institutions on the regional importance of relicts, and presence of threats. | 3. | Assessment of the importance of relicts with local communities. Local threats |
| 4. | Establishes impacts in a preliminary way with indicators. | 4. | Establishes impacts in a detailed way. |

We have progressed by parts, calibrating the possible intensity and types of the sampling. We initially demanded from consultants the execution of several detailed inventories of floristic diversity (using Gentry's methodology) in remnant blocks of original habitats, especially in the Magdalena Valley projects. This has provided us with relevant information on diversity and conservation status of some premontane fragments of original habitats on both watersheds of the mid-Magdalena valley, in the counterfort of the Occidental mountain range and the alluvial plains of the low-Magdalena. Additionally, we have been involving landscape ecology criteria through a proposal made by one of our consultants (Ecorestaurar 1996) who developed a methodology for the study of succession dynamics for ecological restoration, which we implemented in three of our projects.

Because of this "methodological exploring" we now know a good biodiversity characterization does not require significantly greater time and resources than those used in previous studies, and that the causes of the poor quality of the basic information is more related to planning and lack of training of the professionals responsible for the studies. We have a positive attitude towards these two problems and expect them to be solved in the short term. One of the alternatives we have is to establish agreements with institutions (universities, botanical gardens, and non-governmental organizations) who have had experience in biodiversity studies so they can offer their services, including training of personnel, to the big consulting firms.

We are currently engaged in a program of environmental research within the Development Plan for the next five years (ISA 1996) with the purpose of refining our environmental management model. There is a study in progress to develop a methodology for the characterization and management of impacts caused by our transmission lines on birds in Colombia (Roselli and De la Zerda 1997). Two research studies will be starting in 1997; one on the effect of fragmentation on floristic diversity (Mosquera 1996), and the other on the assessment of secondary succession patterns (Vélez and Jiménez 1996), in the moist forest of the base of the Abibe Serranía in the Colombian northwest. Also, in the first semester of 1997, a contract will be given for the study of the adjustment of the methodology created by Dinerstein, Olson and Graham (1995) for the World Wildlife Fund and the World Bank on the assessment of biodiversity conservation status, to the study of route alternatives and environmental impacts in the selected route.

### The use of information

Above all, it is necessary to clarify our assumption that the information produced in biodiversity studies should be as useful as possible for the environmental management of our transmission projects. A good biodiversity characterization is important because it leads to the refining of the Environmental Management Plan (EMP), considered to be the main instrument for environmental management. The EMP assembles the criteria, strategies, management, and programs necessary to prevent, mitigate, and compensate the negative impacts and increase the potential of the positive ones. Some of the applications of the information on biodiversity of the influenced areas in the EMP measures are described as follows:

*Prevention*

The biodiversity inventory of the project zone is used in the making of susceptibility maps and the marking of places with restrictions to the crossing of lines, both in terms of EAA (Environmental Alternatives Analysis) and of EIA (Environmental Impact Assessment). In our particular case, we have been able to use this information to suggest modifications to the final drawing of the route in order to avoid the interruption of original habitats in several projects (Guatapé–Jaguas, La Sierra–Doña Juana, San Carlos–San Marcos, among others). An interesting case showing the importance of involving the social component in the assessment of the biodiversity status is that of the San Carlos–Sabanalarga project where a deviation of the line was made at the direct request of the community to avoid the passing through a relict forest they intended to conserve (ISA 1994).

*Mitigation.*

Since trees may interfere with the line's operation, maintenance people periodically cut the vegetation level with the ground, increasing the potential of fragmentation problems. By knowing the characteristics of short local or regional species, the plant succession in the corridor can be manipulated by planting species that will avoid the growing of trees, and at the same time provide cover and food to the fauna moving between fragments. This same information is useful in the environmental restoration of zones altered or destabilized by the construction of towers or roads. Environmental restoration works have been made in the line passing through the dry forests in the Magdalena Valley, and the Cerromatoso–Urabá line in the Paramillo natural park.

*Compensation*

ISA has a reforestation program it offers the community as a compensation for the effects on vegetation in their territory. We are now working on diversifying the program to include support to local and regional conservation projects. The information obtained in the assessment of the biodiversity status is helpful in identifying suitable areas for these projects and formulating recommendations. It also identifies areas for environmental restoration projects. The publication of the results of these studies in scientific articles or educational booklets increases the scope of the environmental management. Databases and flora and fauna collections contribute to the national biodiversity inventory. We are currently preparing a publication of the flora inventories of the Magdalena Valley.

## CONCLUSIONS

The technical requirements and the activities related to the construction, maintenance, and operation of high voltage power lines in Colombia generate impacts on biodiversity, and the fact that the majority of the infrastructure for the National Interconnected System (NIS) is located in the Andean region and the Atlantic coastal plain makes the situation more complicated. Both regions, but mainly the Andean, have some of the highest levels of biodiversity in all hierarchy scales (alpha, beta, gamma) in the world, and at the same time they are considered to be of high priority in terms of developing conservation plans. Realizing this situation, ISA, who is responsible for the greatest part of the NIS in Colombia, has adopted environmental policies in accordance with the philosophy of sustainable development, and works with an environmental management model which is appropriate for the prevention, mitigation, and compensation of the impacts.

An adequate biodiversity characterization in the areas under the influence of its projects is one of the important basis for the treatment of four fundamental aspects of its environmental management: (a) the process of assessment of alternative routes; (b) the making of susceptibility maps which contribute to the use of the prevention principle in the design of the final corridors for lines; (c) a more precise quantification of puntual impacts and, therefore, better corrective or mitigation measures for the impacts; and (d) inter-institutional relationships that would allow environmental management to go beyond the project limits and be useful for the national biodiversity inventory.

## REFERENCES


Alvarez, E., A.C. Londoño, and A. Cogollo. 1996. Diversidad alfa de plantas vasculares en el sotobosque de un ecosistema de tierra firme en la Amazonia colombiana. Reporte. Fundación Tropenbos-Colombia, Bogotá, 23 p. Sin publicar.

Andrade, G. 1992. Amazonia Colombiana. Fondo FEN Colombia. 73 pp.

Angel, E., S.I. Carmona, and L.C. Villegas. 1996. Gestión ambiental en proyectos de desarrollo: una propuesta desde los proyectos energéticos. Fondo FEN Colombia, Bogotá, 290 pp.

Bierregaard, R.O., T.E. Lovejoy, V. Kapos, A.A. dos Santos, and R.W Hutchings. 1992. The biological dynamics of tropical rainforest fragments. BioScience, 42: 859–866.

Cadena, F., C.B. Calinao, and A. Torres. 1997. Geographic information systems (GIS) and remote sensing application for the selection and environmental evaluation of high voltage transmission line corridors in Colombia. In: Environmental Sciences, Economics and Engineering. R. Williams, J.W. Goodrich-Mahoney, J.R. Wiesniewski, and J. Wiesniewski, eds. Blackwell Sience, Malden, Massachusetts, in press.

Cantera, J. 1993. Oceanografía. In: Colombia Pacífico. P. Leyva, ed. Fondo Fen-Colombia, Bogotá, 1, pp. 12–23.

Cuadros, T. 1992. Distribución ecológica de la fauna de Araracuara. Revista del I.C.N.E., 4(2): 15–30.

Dinerstein, E., D.M. Olson, D.J. Graham et al. 1995. A conservation assessment of the terrestrial ecoregion of Latin America and the Caribbean. The World Wildlife Fund and The World Bank, Washington, D.C., 129 pp.

Duivenvoorden, J.F. 1994. Vascular plant species count in the rain forests of the middle Caquetá area, Colombian Amzonia. Biodiversity and Conservation, 3: 685–715.

Duivenvoorden, J.F. and J.M. Lips. 1995. A land ecological study of soils, vegetation, and plant diversity in Colombian Amazonia: a landscape ecological approach. Serie Tropenbos No. 12, 438 pp.

EcoRestaurar (EcoRestaurar Limitada). 1996. Identificación y calificación de impactos sobre la cobertura vegetal, línea de transmisión Sochagota–Guatiguara. Reporte interno. Sin publicar. Bogotá, Colombia. 20 pp.

Espinal, L.S. and E. Montenegro. 1963. Formaciones vegetales de Colombia. Memoria explicativa sobre el mapa ecológico. Departamento Agrológico Insituto Geográfico Agustín Codazzi, Bogotá. 201 pp.

Folke, C., K-G. Mäler, and C. Perrings. 1992. Biodiversity loss: An introduction. Ambio, 21(3): 200.

Gentry, A.H. 1990. La región amazónica. In: Selva Húmeda de Colombia. B. Villegas, and C.U. Hurtado, eds. Villegas Editores, Bogotá, pp. 53–65.

Gentry, A.H. 1993. Riqueza de especies y composición florística. In: Colombia Pacífico. P. Leyva, ed. Fondo Fen-Colombia, Bogotá, 1: pp. 200–219.

Gentry, A.H. 1992. Patterns of diversity and floristic composition in neotropical montane forests. In: Biodiversity and Conservation of Neotropical Montane Forests. S.P. Churchil, H. Baslslev, E. Forero, and J.L. Luteyn, eds. The New York Botanical Garden, pp. 103–126.

Halffter, G., and E. Ezcurra. 1992. Qué es la biodiversidad?. In La diversidad biológica de Iberoamérica. G. Halffter, ed. Acta Zoológica Mexicana, volumen especial, pp. 3–24.

Henderson, A., S.P. Churchill, and J. Luteyn. 1991. Neotropical plant diversity. Nature, 351: 12–22.

Hernández, J., R.O. Quijano, Th. Walschburger, and A.H. Hurtado. 1992. Estado de la biodiversidad en Colombia. In La diversidad biológica de Iberoamérica. G. Halffter, ed. Acta Zoológica Mexicana, volumen especial, pp. 40–236.

Hernández, J. 1992. Caracterización geográfica de Colombia. In La diversidad biológica de Iberoamérica. G. Halffter, ed. Acta Zoológica Mexicana, volumen especial, pp. 40–236.

Hilty, S.L. and W.L. Brown. 1986. A Guide to the Birds of Colombia. Princeton University Press, Princeton, New Jersey, 836 pp.

Instituto Geográfico Agustín Codazzi (IGAC). 1995. Mapa de suelos de Colombia, 632 pp.

ISA. 1994. Evaluación ambiental sectorial: Sector eléctrico colombiano. Medellín-Colombia, 250 pp.

ISA. 1996. Plan de desarrollo 1996–1996. Medellín-Colombia, 35 pp.

Jongman, R.H., C.J.F. ter Braak, and O.F.R. van Tongeren. 1987. Data analysis in community and landscape ecology. Pudoc, Wageningen, 299 pp.

Kattan, G.H., H. Alvarez, and M. Giraldo. 1994. Forest fragmentation and bird extinctions: San Antonio eighty years later. Conservation Biology, 8(1): 138–146.

Kattan, G.H., and H. Alvarez. 1996. Preservation and management of biodiversity in fragmented landscapes in the Colombian Andes. In: Forest Patches in Tropical Landscapes. J. Schelhas, and R. Greenberg, eds. Island Press, Washington D.C., pp. 3–18.

Kikawa, J. 1990. Biological diversity of tropical forest ecosystems. In: IUFRO (International Union of Forest Research Organization). Report 19th World Congress. Montreal, 2: 173–184.
Korning, J., K. Thomsen, and B. Ollgaard. 1991. Composition and structure of a species rich Amazonian rain forest obtained by two different sample method. Nordic Journal of Botany, 11: 103–110.
Londoño, A.C., and E. Alvarez. 1997. Composición florística de dos bosques (tierra firme y várzea) en la región de Araracuara, Amazonia colombiana. Caldasia, in press.
Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, New Jersey, 179 pp.
Mosquera, L.E. 1996. Composición, estructura y diversidad florística de bosques fragmentados en la cuenca alta del río Sinú con especial énfasis en el sector Cerromatoso-Tierralta de la línea de transmisión de energía. Anteproyecto de tesis M.Sc. Universidad de Antioquia, Medellín, Colombia, p. 9.
Murcia, C. 1995. Edge effects in fragmented forests: Implications for conservation. Trends in Ecology and Evolution, 10: 58–62.
Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology, 4(4): 355–364.
National Research Council. 1992. Conserving biodiversity: A research agenda for development agencies. Washington D.C., 127 pp.
Rangel, J.O., and P. Lowy. 1993. Tipos de vegetación y rasgos fitogeográficos. In: Colombia Pacífico. P. Leyva, ed. Fondo Fen-Colombia, Bogotá, 1: 182–198.
Roselli, L., and S. de la Zerda. 1997. Estudio de los efectos de las líneas de transmisión sobre la avifauna colombiana. Reporte, Interconexión Eléctrica S.A. (ISA), Medellín, 180 pp. Sin publicar.
Ruíz, P., J. Hernández, and M.C. Ardila. 1993. La herpetofauna. In Colombia pacífico. P. Leyva, ed. Fondo Fen-Colombia, Bogotá, 1: 256–269.
Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: A review. Conservation Biology, 5(1): 18–32.
Schelhas, J., and R. Greenberg, eds. 1996. Forest patches in tropical landscapes. Island Press, Washington D.C., 425 pp.
Shafer, C.L. 1995. Value and shortcomings of small reserves. BioScience, 45: 80–88.
Sobrevila, C. and P. Bath. 1992. Evaluación ecológica rápida: un manual para usuarios de America Latina y el Caribe. The Nature Conservancy, Arlington, Virginia, 232 pp.
Solbrig, O. 1992. The IUBS-SCOPE-UNESCO program of research in biodiversity. Ecological Applications, 2(2): 131–138.
Stiles, F.G. 1993. La avifauna. In: Colombia Pacífico. P. Leyva, ed. Fondo Fen-Colombia, Bogotá,. 1: 248–255.
Terborgh, J., and B. Winter. 1983. A method for siting parks and reserves with special reference to Colombia and Ecuador. Biological Conservation, 27: 45–58.
Turner, I.M. 1996. Species loss in fragments of tropical rain forest: A review of evidence. Journal of Applied Ecology, 33: 200–209.
UNESCO (Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura), PNUD (Programa de las Naciones Unidas para el Medio Ambiente) and FAO (Organización para la Alimentación y la Agricultura). 1982. Ecosistemas de los bosques tropicales: Informe sobre el estado actual de conocimientos. UNESCO, Madrid, 771 pp.
Urrego, L.E. 1994. Los bosques inundables del Medio Caquetá, Amazonia colombiana: caracterización y sucesión. Ph.D. Dissertation. University of Amsterdam, Amsterdam, The Netherlands.
van Velzen, H.P. 1991. Prioridades para la conservación de la biodiversidad en los Andes colombianos. Artículo presentado en el Seminario Intenacional sobre Ecosistemas de Montañas Tropicales. Popayán, Colombia, 5–15 Diciembre 1991.
Vélez, D.I., and E.M. Jiménez. 1996. Estudio de la sucesión vegetal en áreas de pastoreo en el Magdalena medio, Puerto Nare (Antioquia). Proyecto tesis de Ingeniería Forestal. Universidad Nacional de Colombia, Medellín, 14 pp.
Wilson, E.O. 1988. The current state of biological diversity. In: Biodiversity. E.O. Wilson, and F.M. Peter, eds. National Academy Press, Washington D.C., pp. 3–18.

## *BIOGRAPHICAL SKETCH*

***Esteban Alvarez Dávila***
*ISA, Calle 12 Sur No. 18-168, Medellín, Colombia*

Esteban Alvarez Dávila is a Forestal Engineer from the Universidad Nacional de Colombia and has a Masters of Science in Biology from the Universidad de Antioquia (Colombia). He has been a researcher for the Tropenbos Program with the Netherlands government, located in the Colombian Amazonian for five years. He is currently an Environmental Especialist in Interconexión Electrica, ISA, Medellín, Colombia.

# Mulching Wetlands after Pipeline Construction: Effects on Plant Diversity and Density

Timothy L. Andersen and Gayle M. Konik

Wetland vegetation recovery following ground disturbance associated with construction along a corridor is generally not well understood. Land management agencies and project sponsors share the objective to quickly and effectively reestablish stable vegetation to control erosion. Mulch is commonly used to promote rapid plant growth by retaining soil moisture and reducing erosion in upland areas. The benefits of mulch application are less clear in wetlands. Land management agencies overseeing a pipeline construction project in southeastern Michigan wished to determine the benefits or disadvantages of mulching wetlands. This report compares post-construction vegetative recovery of wetlands mulched with straw with wetlands not receiving mulch, as measured by plant diversity (number of plant species per test plot) and density (number of specimens per test plot). Measurements were taken two, nine and eleven months after the completion of construction restoration. Factors influencing recovery rate were location of study wetlands, local conditions and susceptibility of study wetlands to invasion by exotic or opportunistic species. Study results yielded conflicting trends. Wetlands receiving mulch treatment did not overall appear significantly different from reference wetlands. Location of wetlands (i.e., proximity to drains, forests, etc.), seasonal factors (including precipitation and temperature) and topographic features seem to greatly overshadow any effect of mulch application to wetlands on plant density and diversity as measured in this study. Longer term examinations (multiple growing seasons) are needed to establish the effectiveness of mulch application to wetlands following pipeline construction.

*Keywords:* Wetlands, pipeline construction impacts, mulch, plant diversity and density, variability, local conditions, revegetation

## BACKGROUND

A 36-inch diameter underground natural gas pipeline was constructed in southern Michigan between July and November 1993. The project sponsor, Great Lakes Gas Transmission Company (Great Lakes), sought permits and approvals from the Federal Energy Regulatory Commission (FERC) and other agencies including the Michigan Department of Natural Resources (DNR) to construct the new pipeline facilities.

The DNR permits required Great Lakes to apply mulch during restoration in wetlands affected by the project. However, FERC does not permit the use of mulch in wetlands. FERC and the DNR reached an agreement requiring Great Lakes to establish an experimental program lasting one year that was designed to study the benefits and/or disadvantages of using mulch during the restoration of wetlands.

## STUDY BASIS AND SITE SELECTION

Great Lakes' pipeline expansion project was constructed in southeastern Michigan from July to November 1993. The pipeline project was constructed in two segments. The north segment contains 11 wetlands and the south loop contains 10 wetlands that were affected by construction of the new project. The wetlands were delineated to determine the wetland-upland boundaries. Twelve wetlands were selected for

**Table 1. Plants commonly found in the study wetlands**

| | |
|---|---|
| *Acer* spp. | *Lollium* spp. |
| *Alisma* spp. | *Mimulus* spp. |
| *Apia* spp. | *Panicum* spp. |
| *Aster* spp. | *Penthorum* spp. |
| *Betula* spp. | *Phalarus* spp. |
| *Carex* spp. | *Phragmites* spp. |
| *Cirsium* spp. | *Plantago* spp. |
| *Cyperus* spp. | *Poa* spp. |
| *Digitaria* spp. | *Polygonum* spp. |
| *Eleocharis* spp. | *Populus* spp. |
| *Elytrigia* spp. | *Scirpus* spp. |
| *Epilobium* spp. | *Sium* spp. |
| *Equisetum* spp. | *Solidago* spp. |
| *Fragaria* spp. | *Typha* spp. |
| *Juncus* spp. | *Verontea* spp. |

this study, based primarily on accessibility for field observations. Wetlands were also selected for this study based on similarity of size, and type of function and structure. Wetlands in this study contained similar assemblages of plant species (Table 1).

Wetland construction activity involved mechanical clearing to ground level of virtually all vegetation on the construction right-of-way. During trench excavation, topsoil from the area directly over the trench was segregated from the subsoil and stockpiled. After installation of the pipeline, the topsoil was returned to its original horizon and the wetlands were restored to pre-construction contours. No foreign fill was imported into the wetlands. Wetlands that were not saturated were seeded either by tractor or by hand with annual rye seed as a temporary cover. Seed was applied at a uniform rate of 40 pounds per acre. Mulch was applied in September 1993 at a rate between 0.5 and 1.0 tons per acre in study wetlands to be mulched. Straw mulch free of weed seed was applied by hand or mulch blower and, if necessary, anchored. Mechanical anchoring consisted of a crimping tool used in wetlands where mulch was susceptible to removal by wind at the time of application. Mechanical crimping was not conducted if soil conditions did not allow access of equipment.

## METHODOLOGY

### Study design

The study was designed to allow a statistical comparison of areas treated with mulch (treatment areas) and unmulched areas (reference). The study includes two designs (Fig. 1); one treatment regime allows the examination of mulching effects *between* wetlands (full design) with the entire wetland receiving either no mulch (reference) or straw mulch (treatment). Four wetlands in the full design were completely mulched and four wetlands served as reference. The second design examines the effect of mulching *within* wetlands (split design). Each wetland in this design was split in half with one half receiving no mulch (reference) and the other half receiving straw mulch (treatment).

In both the full and split designs, effects were determined by measuring a variety of parameters (i.e. species diversity, frequency and percent cover of vascular plant species) observed within each test plot and comparing

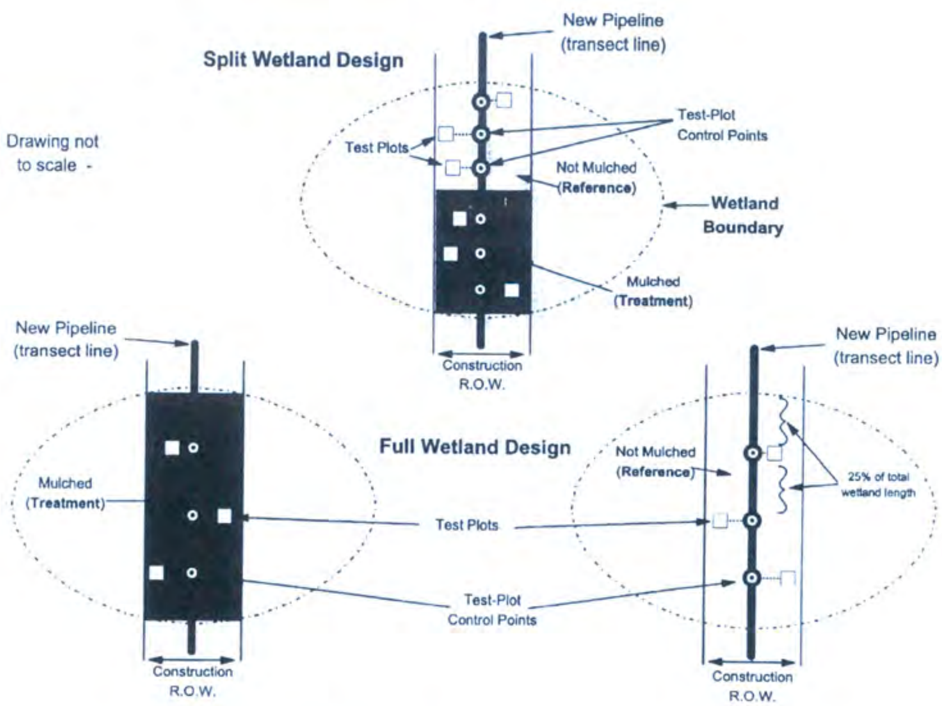



Fig. 1. Wetland sampling schematic.

the measurements between the treatment and reference. The presence of exotic and nuisance species were recorded because mulch is a potential seed source for undesirable plant species.

In the split wetland design, straw mulch was applied to one half of the entire construction right-of-way, as indicated in Fig. 1. The unmulched portion of the wetland served as a reference.

In the full wetland design, straw mulch was applied to four wetlands for their entire length within the construction right-of-way, as indicated in Fig. 1.

### Data collection

In the full wetland design, three control points were established on a line located directly over the new pipeline: two 25% from either boundary of the wetland, and one at the mid-point of the wetland (Fig. 1). A half-meter-square (50×50 cm) test plot was established on a line perpendicular to the pipeline at each of the control points. A random number table was used to determine the distances between the control points and the test plots. Test plots were placed north of the control point for even-numbered distances, and south of the control point for odd-numbered distances. The locations of the test plots were determined in the same manner as described above for the split wetland design, except that six plots were established instead of three (Fig. 1). The plots were staked so subsequent observations could be taken at the same locations.

Three sampling events were undertaken during the course of this study. The first event occurred in November 1993, approximately two months after restoration was completed for the pipeline project. The second sampling event was conducted in June 1994. The third sampling event occurred in September 1994.

During each sampling event and within each test plot, one measurement was taken for each of the following:

1. species diversity — number of species per plot,
2. species density (frequency) — number of specimens per species,
3. plant density — estimate of percent cover of vascular plants.

Additional information recorded during data collection included weather conditions, observations of local hydrologic conditions, presence of noxious or exotic species near or within test plots, and evidence of disease or infestation affecting the wetland plant community.

## RESULTS

### Fall 1993

Four of the twelve wetlands in the study exhibited new plant growth primarily composed of annual ryegrass planted during project restoration. The eight wetlands that did not show plant growth had standing water present that completely covered the test plot sites. In four of the eight wetlands with standing water, new test plots were selected using the site selection method described above such that plots could be established in areas not covered with water. Subsequent sampling events occurred within the reselected sampling plots.

One wetland appeared to have an upland seed mix sown in addition to the annual ryegrass prescribed for the wetland, although records of seeding do not support this observation. Definitive plant species identification was difficult because the vast majority of specimens were less than two months old and had germinated late in a cold, wet growing season. No evidence of disease or infestation by noxious or exotic

**Table 2. Summary statistics**

| | Frequency (no. plants) | Percent cover | Diversity (no. species) |
|---|---|---|---|
| *Fall 1993 data* | | | |
| Mean | | | |
| Full design – mulched | 29.8 | 20.7 | 1.3 |
| Full design – unmulched | 35.5 | 11.0 | 1.3 |
| Split design – mulched | 20.0 | 3.0 | 1.1 |
| Split design – unmulched | 20.3 | 8.3 | 1.3 |
| Standard deviation | | | |
| Full design – mulched | 25.8 | 30.4 | 0.4 |
| Full design – unmulched | 18.4 | 14.8 | 0.8 |
| Split design – mulched | 16.5 | 0 | 0.2 |
| Split design – unmulched | 4.9 | 6.5 | 0.2 |
| *Summer 1994 data* | | | |
| Mean | | | |
| Full design – mulched | TNTC[1] | 20.7 | 1.7 |
| Full design – unmulched | 12.9 | 23.6 | 2.6 |
| Split design – mulched | 7.9 | 9.3 | 2.1 |
| Split design – unmulched | 14.9 | 20.0 | 2.3 |
| Standard deviation | | | |
| Full design – mulched | n/a[1] | 28.8 | 1.5 |
| Full design – unmulched | 10.2 | 26.7 | 1.2 |
| Split design – mulched | 7.9 | 10.3 | 1.9 |
| Split design – unmulched | 27.2 | 27.1 | 2.1 |
| *Fall 1994 data* | | | |
| Mean | | | |
| Full design – mulched | 14.4 | 48.0 | 3.0 |
| Full design – unmulched | 20.3 | 50.8 | 4.5 |
| Split design – mulched | 22.5 | 63.8 | 4.0 |
| Split design – unmulched | 13.3 | 61.3 | 3.8 |
| Standard deviation | | | |
| Full design – mulched | 13.9 | 44.5 | 2.5 |
| Full design – unmulched | 12.5 | 31.4 | 2.5 |
| Split design – mulched | 16.8 | 32.1 | 2.6 |
| Split design – unmulched | 10.8 | 26.2 | 2.9 |

[1]TNTC = too numerous to count. n/a = not applicable.
Mean values and standard deviations were calculated based on measurements taken from three plots per wetland. Eight wetlands (four reference, four treatments) were included in the full design and four wetlands (each with half as reference and half receiving treatment) were included in the split design.

plant species was observed during the sampling event.

The sample means and standard deviations were highly variable, precluding a meaningful use of comparative statistical analysis of data collected during this sampling event (Table 2). No further statistical analysis was employed; no conclusions were drawn from the data.

### Summer 1994

Water levels in the study wetlands had remained relatively high since the fall 1993 sampling event. Due to abundant precipitation, all wetlands in the study had areas of standing water. The hydrologic conditions of the test plots ranged from somewhat saturated to completely inundated. One wetland was not sampled because turbid water prevented direct observation of the presence of plants in the test plots.

Plant growth in the wetlands seemed generally poor compared to nearby upland areas recovering from pipeline construction. As in the first sampling event, disease was not evident. Three of the wetlands had exotic species (*Phalaris* spp., *Phragmites australis*, Voss 1972, 1985) growing near the right-of-way. Many of the plants observed in the wetlands were immature. These immature plants appeared incapable of producing seed stock during the 1994 growing season. Some vegetation apparently had established from root stock left intact during construction, however, this type of vegetation did not account for a significant portion of the vegetative cover.

Statistical analysis of the measured parameters did not reveal a significant difference between the mulched and unmulched wetlands in either the full or split wetland design. Sample means were moderately variable, reducing the reliability of statistical comparison (Table 2). Analysis of variance (ANOVA) comparisons (Snedecor and Cochran 1980, Sokal and Rohlf 1981) did not reveal a statistically significant difference between the mulched mean values and the unmulched mean values. Statistically significant differences between means measured between wetland halves in the split plot design were revealed but the significance of this difference is not related to the presence or absence of mulch within the plots (Table 3). The study wetlands were inherently patchy with regard to moisture, soil conditions, etc.

### Fall 1994

Excess surface water appeared to affect plant growth within the study wetlands, consistent with previous sampling event observations. One wetland was completely inundated with water and was not sampled.

Plant abundance was greater than observed during the previous two sampling events. For all of the parameters measured in both the full and split mulch design, the mean values were greater than the previous sampling event, especially means for plant cover (density) and species density (frequency). No evidence of disease was observed. One wetland appeared to be in the early stages of invasion from *Phragmites australis*.

Analysis of the data indicated a general trend toward uniformity of variances for the means of each parameter (Table 2). ANOVA comparisons of the mulched and unmulched mean values revealed statistically significant differences between means for species diversity in the full wetland design and between means for density in the split wetland design (Table 3). Diversity appeared to be inhibited by the presence of mulch in the full mulch wetlands compared to unmulched diversity values. The presence of mulch appeared to stimulate the density of plants in the split wetland

**Table 3. Summary of ANOVA results – significant difference between means[1]**

| Parameter | Full wetland design | | Split wetland design | |
|---|---|---|---|---|
| | Treatment[2] | Location[2] | Treatment[3] | Location[3] |
| Fall 1993 | Highly variable standard deviations precluded meaningful statistical analysis | | | |
| Summer 1994 | | | | |
| No. of plants | no difference | no difference | no difference | sig. difference |
| Percent cover | no difference | no difference | no difference | sig. difference |
| No. of species | no difference | no difference | no difference | sig. difference |
| Fall 1994 | | | | |
| No. of plants | no difference | sig. difference | stimulation | sig. difference |
| Percent cover | no difference | sig. difference | no difference | sig. difference |
| No. of species | inhibition | sig. difference | no difference | sig. difference |

[1]Significant difference between means defined at $p \leq 0.1$.
[2]Difference between means: Treatment = significant difference between mulch and no mulch. Inhibition = value lower in mulch plot. Stimulation = value higher in mulch plot. Location = significant portion of variance ascribed to patchiness of wetland.
[3]In the split wetland design, difference between treatment means was not significant but variance between wetland halves accounted for a significant portion of the total variance.
As in Table 2, mean values and standard deviations were calculated based on measurements taken from 3 plots per wetland.

design. In the split wetland design there were statistically significant differences in all measured parameters based upon location. As with the Summer 1994 observations, the study wetlands were patchy which had a significant influence on the measured parameters in the full wetland design. In every parameter measured, patchiness contributed to some of the difference between mulch and unmulch values.

## DISCUSSION

The highly variable nature of the data from the first sampling event does not lead to a statistically significant conclusion regarding the effect of mulch application in wetlands. The variability of the data is likely due to several reasons. Chief among them is the relatively short period of time from restoration to the sampling events. Recovery of wetlands takes several growing seasons before diversity of plant species and coverage approaches that of undisturbed wetlands. Also, newly emerging wetland plant communities are inherently patchy. Until the disturbed wetlands stabilize, diversity and frequency of plant species are likely to be highly variable and less than that of stable, undisturbed wetlands.

General observations of the study wetlands indicated varying degrees of recovery of wetland function and structure. A wet winter, spring and summer following seeding and mulching left most of the study wetlands inundated with open water. Recovery of plant communities from construction-related disturbance is slower in open water systems. Poor growth observed during both sampling events may be attributable to:

- High water levels delaying or preventing seed germination, causing reduced growth in the wetland plants.
- Postconstruction soil conditions that are not conducive to annual plant growth and seed production.

As the study wetlands began to recover from disturbance, variation of the measured parameters became less. Influences such as the presence or absence of mulch, and wetland patchiness (which includes factors such as topography, microclimatic and biotic amelioration, soil types, available light, etc.) can be addressed through statistical analysis. The trend of wetland location contributing to the differences of the measured parameters became more pronounced as the growing season progressed.

When the effects of wetland patchiness are considered, the effects of mulching wetlands as measured by plant diversity and density yield unclear results. Plant diversity was inhibited by the presence of mulch in the full wetland design while plant density was stimulated by the presence of mulch in the split wetland design. These results were observed only during the last round of sampling. Even though the relative inhibition of diversity and stimulation of density was observed only during the last sampling event, the overall trend indicates that wetlands are affected to a greater extent by their variability and their ability to recovery from disturbance rather than the application of mulch.

## ACKNOWLEDGMENTS

The authors wish to thank David Campbell, Jeff Schultenover and Glenn Vande Water for their creative efforts in the field. A debt of thanks is owed to Jerry Kott who provided support for this study.

## REFERENCES

Snedecor, G.W. and W.G. Cochran. 1980. Statistical Methods. 7th edn. The Iowa State University. Ames, Iowa.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. 2nd edn. W.H. Freeman and Company. San Francisco, California.

Voss, E.G. 1972. Michigan Flora, Part I. Gymnosperms and Monocots. Cranbrook Institute of Science. Bloomfield Hills, Michigan. 488 pp.

Voss, E.G. 1985. Michigan Flora, Part II. Dicots. University of Michigan Press. Ann Arbor, Michigan. 724 pp.

## *BIOGRAPHICAL SKETCHES*

***Timothy L. Andersen***

*Senior Scientist, Natural Resource Group, Inc., 1800 International Center, 900 Second Avenue South, Minneapolis, MN 55402, USA*

Mr. Andersen is employed as a scientist and project manager at Natural Resource Group, Inc. in Minneapolis, Minnesota. Mr. Andersen received his M.S. in Ecology from the University of Minnesota and has been involved in original research concerning environmental fate of chemicals in aquatic systems. More recently, he has worked on environmental issues related to new and existing pipeline operations and construction.

***Gayle M. Konik***

*Manager, Environmental Permitting, Great Lakes Gas Transmission Company, One Woodward Ave., Suite 1600, Detroit, MI 48226, USA*

Ms. Konik is Manager of Environmental Permitting for Great Lakes Gas Transmission Company in Detroit, Michigan. She has worked in the natural gas industry for the last six years having made the transition to industry after eight years of experience as a regulator for the U.S. Army Corps of Engineers. Ms. Konik's primary areas of interest include wetland impacts from construction, cultural resources and restoration issues. Ms. Konik received a B.A. in Environmental Studies and Anthropology from Wayne State University.

# Fragmentation and Road-Infrastructure in The Netherlands: From History to Future

**G.J. (Hans) Bekker**

In the highly populated Netherlands, intensive landuse and a huge road network have resulted in a highly fragmented landscape. The impact on several fauna species is great. In the 1970s, action groups began to ask for attention to be given to the problem of fragmentation by infrastructure. The first measures taken along motorways were for the badger *Meles meles*, an endangered species in the Netherlands. Much has been learned during this period about the process, the technical and ecological possibilities, and the approach to defragmentation in the Netherlands. The experiences are used in policy, research items and a wide variety of measures. Some of these learning points are described in this paper. The process included much discussion and it appears that people from different disciplines need each other. Communication between and information to all participants of the process are vital. Various authorities have translated the experience into objectives and programmes. The policy now in the Ministry for Transport, Public Works and Water Management is to avoid from the start any new fragmentation. Where avoidance is impossible the damage by fragmentation should be mitigated, and when mitigation is not enough, the loss of nature must be compensated. A range of measures has been implemented: simple pipes, redesigned culverts, ecoducts and so named walls of tree-stumps as a modification to existing constructions beneficial to animals. Some measures became a standard feature in the design of new roads, while special projects were set up to equip existing roads with these facilities for all kinds of species. At the moment there is a plan until 2002 to avoid problems and to solve the main problem points caused by existing roads. Research is necessary to realize these measures. Research concerning the impact of roads and traffic on all kinds of species is needed to predict the effects in EIAs and to translate the ecological knowledge into methods and measures. It is a fact that most of these measures are used by animals: tracks have been seen on sand beds. The effectiveness of measures on the development of populations of target species around a new highway is unsure. It is obvious that an evaluation of the policy must also be carried out.

*Keywords*: Habitat fragmentation, mitigation, compensation, badger pipes, ecoducts, road infrastructure

## INTRODUCTION

This paper describes how Rijkswaterstaat (the department responsible for motorways within the Ministry of Transport, Public Works and Water Management) learned to counteract the problem of fragmentation caused by infrastructure and what needs attention.

In the Netherlands, nature is becoming less varied through all kinds of human activities. Fragmentation is one of the causes. As well as the large scale and intensification of agriculture, expanding villages and industrial area's roads and canals fragment nature.

The total length of the motorway network between 1950 and 1990 has increased from less than 100 km to 2100 km and, on some stretches, more than 100,000 vehicles travel daily. The average distance people travel by car per annum has also increased dramatically (see Table 1).

Fragmentation is the overall impact of infrastructure on nature. It subdivides ecosystems and habitats for plant and animal populations into smaller, isolated patches. Certain species can no longer survive on such small pieces of habitat.

Fragmentation has four types of impact:

**Table 1. Average distance people travel by car per annum**

| Year | km |
|---|---|
| 1920 | 75 |
| 1950 | 500 |
| 1980 | 7500 |
| 1993 | 9500 |

1. habitat destruction by the physical presence of the motorway;
2. disturbance of habitats;
3. insurmountable barriers for many animals of various species;
4. wounding and killing of animals by road traffic.

These impacts cause degradation and loss of habitat, disintegration of habitats into smaller and separated areas, and loss of individuals of species. To reduce this damage restoration of safe faunal movements from one patch to another is very important (Verkaar and Bekker 1991). Migration, as all movements from one spatial unit to another, is the key to the use of the area (daily or yearly) and for recolonization after local extinction.

## HISTORY

The Dutch history of defragmentation measures has a strong connection with the attention given to the badger *Meles meles* (Bekker and Canters 1997). The badger is an endangered species in the Netherlands and has been protected by law since 1947. Its decline in this century is enormous, declining to approximately 1,200 individuals around 1980. Some 20–25% of the total population died annually as road victims. This steep decline in the 1960s and 1970s made protection necessary. The first steps to prevent badgers being killed when they cross the road led to the current approach of defragmentation using badger pipes. This process was one of trial and error, but the approach now, related to all kinds of species, is based on this 20-year experience.

*Up to 1975*
The first badger tunnel was built: a concrete pipe 0.80 m in diameter, under a new road, no associated fence erected, many questions.

*1976–1980*
Another four badger tunnels built: concrete 0.80 × 1.20 m under a new motorway, fenced but unsatisfactory. Much heated discussion whether these tunnels should have been built and whose responsibility it was.

*1981–1985*
Five badger tunnels built: concrete pipes 0.30 m and 0.50 m in diameter under a new motorway. The discussion focused on design, dimensions, costs, place and responsibility. The fencing was better, reinforced galvanized, spot-welded Casanet-Netting. Engineers and policy makers start to ask about the use of the measures and became interested in this topic. During this period the first tunnels for local roads were constructed in relation to the measures for motorways. Also conducting measures in the neighbouring landscape were taken. Cooperation between various players (levels of government, farmers, hunters, police, nature clubs, etc.) appeared to be necessary to improve the effectiveness of several measures.

During construction and after the opening of the motorway, the first data about usage were gathered. These data indicate that the pipes were used frequently by badgers as well as by other species (Derckx 1984). In this period some lectures for civil engineers about this topic were given.

Part of the process was the pressure and knowledge of one activist organization who made a valuable contribution to the adoption of protective measures.

*1986–1990*
Forty badger tunnels built: pipes of concrete and steel under new motorways and the first steel pipe under an existing motorway. Satisfactory fencing and little discussion. Road engineers became interested. Some questions were raised about maintenance of the measures and the siting of fences. More and more, the use of the habitat became part of the implementation of the measures. The first two ecoducts (Woeste Hoeve and Terlet, Rw A50) were built.

Several talks were given in schools about fragmentation and possible measures, and a four-day course was set up for designers (Rijkswaterstaat 1990). Information about design, material, location and the use of a badger-tunnel was documented in a leaflet and in a video.

*1991–1995*
In areas where the badger lives or possibly can live in the future, badger tunnels became a standard feature in the design and construction of motorways. A special project was set up to counteract the road victims at existing roads (Rijkswaterstaat, project 50 pipes, 1991–1994). Road victims formed the basis for identification of the problems between badgers and motorways. Ingenious solutions related to technical problems (waterlevel, little space) were necessary. The badger population rose to around 2,200 individuals in 1991 (Wiertz 1991).

The third ecoduct (Boerskotten, Rw A1) was built. Other mitigation measures were realized: stump walls, fauna passages in culverts. In 1993, the program Fragmentation ... Defragmentation (Rijkswaterstaat 1993) started and focused on the period to 1997. This program was partly based on the experience of the history of badgers and continued with measures for badgers beside other species.

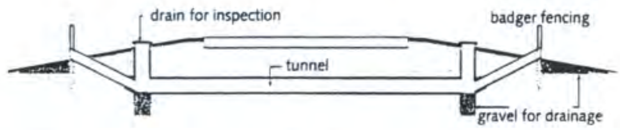



Fig. 1. Design of a tunnel for badgers or other small wildlife.

A manual was written containing information about the purpose, approach, design, technical realization and maintenance of all the measures (Rijkswaterstaat et al. 1995) (Fig. 1).

*Since 1996*

The program is continued with the renewed program in 1997 focused on the period until 2001. Badgers are one of the species for which measures are taken. The badger population is still growing: 2,400 in 1996 (Bekker and Canters 1997). Now there is a broad-scale planning to address fragmentation. Engineers and biologists continue to cooperate to achieve the political objectives of counteracting the fragmentation by motorways. Several ecoducts and big fauna underpassages are being planned or are under construction.

## LESSONS FROM THIS HISTORY

We have learned much during this 20-year period, particularly about cooperation, technical and ecological possibilities. The experiences are used for the policy, for research items and for a wide variety of measures. The history of the measures for the badger also helped Rijkswaterstaat to achieve a more comprehensive approach for defragmentation.

### Participants

From the history described it became clear that many people are involved. Citizens and action groups are part of the process as they often have a great deal of knowledge about specific species or the local natural situation. Action groups protested increasingly loudly that the damage to nature by road building and road use must stop. They first drew attention to the issue with letters, interviews and articles in newspapers, but later more drastic methods were used. Finally, they succeeded in getting attention; and their knowledge could often be used without losing their critical voice.

Much discussion was necessary to establish that the road administration was responsible for measures along the road. But questions by engineers and authorities about responsibility and costs changed slowly into objectives to counteract the fragmentation of the landscape by road building. These mean responsibility for avoidance of fragmentation and measures for existing fragmentation. Other authorities, nature conservation clubs and farmers are responsible for entire measures in the surroundings. These groups must cooperate to achieve real solutions to fragmentation.

It took time before the various disciplines understood each other. Biologists had to apply themselves to exact, more mathematical information about biological demands. Civil engineers had to learn that ecological processes are complex and not always predictable. These gaps were, however, bridgeable.

### Government policy

During the 1980s, fragmentation became an important issue for the three Ministries involved (Agriculture, Nature Management and Fisheries; Transport, Public Works and Water Management; Housing, Physical Planning and Environment). It was part of the principal aims of a policy to counteract the decline of nature values. In the Nature Policy Plan, the concept of the National Ecological Network (Ministry of Agriculture, Nature and Fisheries 1990), priority is given to sustainable conservation, recovery and development of nationally and internationally important ecosystems. For infrastructure in the Second Transport Structure Plan (Ministry of Transport, Public Works and Water Management 1990), the following goals were established to be achieved within twenty years: "In the short term further fragmentation of nature and landscape will have been prevented; in the long term the fragmentation will have been pushed back".

In 1993, a rough framework existed within the Green Space Structure Plan (Ministry of Agriculture, Nature and Fisheries 1993) for compensatory measures. The principle underlying compensation was that there should be "no net loss" of the area of ecological value as a result of constructing infrastructure.

The Road and Hydraulic Engineering Division, as part of the Ministry of Transport, Public Works and Water Management, was given the task of implementing this policy around motorways. The targets were (Rijkswaterstaat 1993):

- 2000: 40% of the problem points between the National Ecological Network and the existing main infrastructure will be 'resolved',
- 2010: 90% of these problem points will be 'resolved',
- in situations where mitigation is not possible, compensation measures will be implemented.

### Approach

Based on this policy, fragmentation will be counteracted with the following strategy in four connected steps:

1. Preventing fragmentation by avoiding: Environmental Impact Assessment, no new infrastructure, better utilization of existing infrastructure, avoiding vulnerable habitats by route planning, underground infrastructure, good designs of the road. At this stage, the need for mitigation work can be reduced (Kirby 1997).
2. Removing and reducing fragmentation by mitigation measures: influencing road use by reducing speed, reducing the volume of traffic and selective

**Table 2. The realized measures in 1993, 1994 and 1995**

| Region | 1993 | 1994 | 1995 | Measures |
|---|---|---|---|---|
| North Netherland | 5 | 6 | 9 | small wildlife tunnels, catwalks, stumpwall |
| East-Netherlands | 13 | 13 | 6 | small wildlife tunnels, fencing, catwalks |
| Flevoland | 2 | 3 | 1 | catwalks and stumpwall |
| Utrecht | 1 | 1 | 2 | stumpwall, joint use viaduct, tunnel improvement |
| North-Holland | 1 | 2 | 5 | catwalks in bridge, stumpwall |
| South-Holland | – | 3 | – | catwalk in culvert, small wildlife tunnel, fencing |
| Zeeland | 2 | – | – | small wildlife tunnel, catwalk in culvert |
| Noord-Brabant | 1 | 1 | 1 | banks in culverts |
| Limburg | – | 3 | 2 | small wildlife tunnel, fencing |
| Total | 25 | 32 | 26 | |

road use; passages under and over infrastructure as badger-tunnels and ecoducts and improve the joint use of existing viaducts and bridges; screening roads and railways with fencing, shrubs or warning signs.

3. Increasing the acreage set aside for conservation areas: compensation of land with nature development, nature habitat improvement, partial closure of minor road network.
4. Improving habitat quality: taking noise measures, light and visual measures, ecological design and maintenance of roadside verges.

## Implementation

Currently, nature is decreasing, partly because roads are built and used, so it is obvious that something has to be done to decrease fragmentation. There is no time to wait for results of research. Regional directorates of the Rijkswaterstaat are implementing all kinds of measures, based on their own analyses. There is a planning until 2002. The measures realized in 1993, 1994 and 1995 are shown in Table 2 (Bekker 1996). The realization of these measures yields much information about possibilities and problems. Representatives of the regional directorates regularly discuss their experiences.

## Effects of roads and traffic on nature

Although the implementation of measures must be continued, there is still a need for research. Our research is focused on effects of road building and use of motorways on several species or group of species. It is necessary to know which species are affected by infrastructure and how much they are affected. Within the Road and Hydraulic Engineering Division, studies have been carried out about the effects on amphibians (Vos and Chardon 1994), squirrels (Nieuwenhuizen and Van Apeldoorn 1995), hedgehogs (Mulder 1996), and badgers, small mammals, ground beetles and breeding birds (Reijnen, Veenbaas and Foppen 1992).

Several studies are carried out to underline the large number of victims. Yearly, 20–25% of the badger population falls victim to the car (Bekker 1997). Van den Tempel (1993) estimated that roughly 1–2 million birds a year are road victims, this occurring in such a small country as the Netherlands. The study by Groot Bruinderink and Hazebroek (1996) shows strong evidence of some patterns (place, time — daily and seasonal, sex composition) in the number of victims. This information can give ideas for mitigation measures.

## Methods to predict effects

From this knowledge about the impact on species, methods are being developed for predicting effects. These effects are predictable when information is highly quantified: loss of acreage or numbers of a species. The work by Reijnen is being used for a method of predict the effect on breeding birds along motorways (Reijnen, Veenbaas and Foppen 1992).

The loss of habitat is simple to quantify: each kilometre of motorway (two directions with three lanes and shoulders) covers at least 35,000 $m^2$ with asphalt. Noise and emissions cause a decline in the quality of the environment and reduce the suitability of the area as habitat. This effect is gradual (Canters and Cuperus 1997). Although it is difficult to calculate disturbance, because it depends of the species concerned, it is to be quantified and used as a method. For example, the loss of quality by disturbance can be compensated for by developing new sites with an acreage that is a certain percentage of the disturbed acreage.

Animals become cut off from their habitat (i.e., isolation). It is not yet possible to calculate the barrier effect (Canters and Cuperus 1997).

## Methods to identify and prioritize problem points

Several studies are carried out addressing the question of how to identify the problem points. The first approach was based on the intersections between the National Ecological Network and the existing and planned network of highways (Piepers and Bekker 1993). The overlay of two maps is still the principal means of identification and prioritization of problem points. Additional information is also used. Landscape ecological information gives spots with high values. Protected species in the Nature Policy Plan help to identify problem points inside and outside the National Ecological Network and to prioritize.

Data about road victims helps identify specific points where measures can be taken and for which species. Because data about the place of collisions were missing, it was necessary to set up a system to collect these data. Now the system has to be filled with reliable data.

### Design and improvement of measures

At first, a mixture of ecological and civil engineering knowledge and initial design ideas led to measures around roads to protect animals. Now, more and more ecological and civil engineering knowledge and experience are translated into improvements of the measures. However, several questions remain. For example, there is insufficient information about the best shape, material, design and numbers of ecoducts. What kind of human joint use is possible (forest road, cattle strip, agriculture road, hiking path). The ecoducts in the Netherlands differ in many respects from those in other countries (Keller and Pfister 1996, Ministere de l'Equipment et de l'Environnement 1993). The ecoducts in France are probably too small, but the enormous width in Switzerland and Germany is very expensive. Table 3 shows the ecoducts in four countries with their differences in width.

There is a relation between the ecology of a (group of) animal species and the shape, height, width and length of mitigation measures. For example a tunnel for roe deer must have the following size (Bekker 1997):

- length as short as possible,
- height >10% of the length and at least 3.5 m,
- width > two times the height and at least 7 m, and
- the relative cross-section: height × width / length > 0.75.

There are situations when roe-deer use a smaller tunnel or refuse to use a bigger one. The data from all kinds of existing underpassage show that the relative cross-section is the most important parameter (Olbrich 1984, Ministere de l'Equipement et de l'Environnement 1993, Miljoministeriet Danmark 1993).

Many wet sites in the Netherlands are divided by roads. These form a barrier, especially for those animals which travel through the banks along the waters. In culverts or under bridges such a bank often does not continue. To avoid animals crossing the road, we have started to take measures. Boulders, concrete, wooden or plastic horizontal sections are placed along the inner sides of culverts. The place in the culvert and the design of these catwalks are based on the best available knowledge. These catwalks are experimental, but necessary.

Joint use of viaducts and bridges is multiplying the amount of possible fauna underpassages (Bekker 1989, Sips 1994). Often it can easily be increased by providing suitable shelter. At the Zandheuvel Viaduct, an intersection between motorway A27 and the main road from Baarn to Hilversum, an oversized viaduct (anticipating future widening of the main road) was regularly used by roe deer and fox, but not by small mammals (van der Linden 1994). Modifications by a wall of tree stumps, trunks and some additional planting made the passage suitable for voles, mice and shrews. The place is now used as a habitat for these species. Experiences and further research will be necessary to improve these provisions.

**Table 3. Ecoducts in four countries show differences in width**

| Country | Road | Name | Smallest width (m) |
|---|---|---|---|
| Switzerland | N1 | Grauholz | 30 |
| | N7 | Fuchswies | 200 |
| | | Aspiholz | 140 |
| | N8 | Brienzwiler | 14 |
| Germany | B31 | Schwarzgraben | 50 |
| | B31 | Weiherholz | 80 |
| | B31 | Hirschweg | 80 |
| | B31 | Nesselwangen | 29 |
| | B31 | Negelhof | 20 |
| | B33 | ? | 35 |
| | B33 | ? | 35 |
| | DB | ? | 8 |
| France | A36 | Hardt | 8 & 8 & 8 |
| | A36 | Hardt | 12 |
| | A4 | Col d Saverne | 10 |
| | A13 | F.D. de Bord | 5 |
| | A10 | Bois Griffons | 4 |
| | A40 | D Fontaine | 8 |
| | A71 | ? | 9 & 6 & 6 |
| | A5 | ? | 7 & 7 |
| The Netherlands | A50 | Woetse Hoeve | 50 |
| | A50 | Terlet | 50 |
| | A1 | Boerskotten | 15 |
| | A1 (in prep.) | Kootwijk | 35 |

### Evaluation of measures

The questions about place, size, design and surroundings are the reason for evaluating the measures. Facts and data are needed to ascertain their effectiveness. The first step is to monitor whether the planned measures are realized and, from a technical point of view, properly realized. Furthermore, two questions arise when we are dealing with effectiveness: are the provisions used by the animals, and are (sub)populations increasing or at least stabilized?

Several studies prove that measures are well used (Litjens 1991, Derckx 1984, Bekker 1989, Janssen 1995). A sandbed showed that not only were the intended species using the ecoducts (red deer, roe deer and wild boar), but badgers, foxes, martens, beetles and birds were also using. Badgers frequently use the badger-pipes, as do foxes, hares and stoats.

The pipes, culverts and ecoduct near Boerskotten (A1) are investigated on the question of use by sandbeds, traps and PVC tubes containing ink and paper (Nieuwenhuizen and Van Apeldoorn 1995). The main conclusions were:

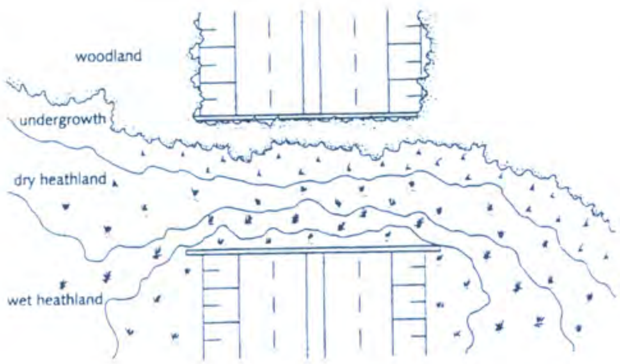



Fig. 2. Ecoduct with several habitat types.

- all of the passages were used; the pipes and culverts by five species of mammals and the ecoduct by nine (except mice and voles);
- species preferred a particular type of passage: fox and rabbit used the pipes more than the culverts and roe deer, hare and red squirrel were only observed on the ecoduct;
- small species such as mice and voles were not observed in the pipes;
- some technical shortcomings were identified and some improvements possible.

It appears that an ecoduct with a variety of habitat-types is better for a broader range of species. Design of an ecoduct is important and so is the context, as is shown in Fig. 2 (from the previously manual).

Few data are available on the use of catwalks (Ward 1996); evaluation is being started by Rijkswaterstaat.

The question of (sub)population levels is very difficult to answer. At first, little data existed at the population level. The well known badger population is an exception. Furthermore, road building takes a long time (10–15 years) from planning to completion and use. During that time, significant changes in populations can occur due to other reasons, and the combination of factors makes it difficult to make causal connections. For example, the growth of the badger population from 1,200 in 1980 to 2,400 in 1996 is the result of several measures in the area that suited as habitat. Beside measures under and along roads the following has changed: the food supply has increased; new hedges and small copses have been established in agricultural land; the protection of setts has improved; a system has been set up to record traffic victims and to find the cubs when a nursing mother has killed. The youngsters are used to restock small subpopulations.

### Evaluation of the policy

The government want to know how their policy is working. For this evaluation, the use of measures is interesting. The effect on populations also affects the policy. As mentioned above, information on this is only partly available.

The annual Policy Evaluation Report charts the progress of the targets of the Second Structure Transport Plan, defragmentation being one of the subjects included in it (Ministry V&W 1996). The basic criterion for now is the number of problem points (the intersection of the National Ecological Network by the existing main infrastructure) solved. Using the number of problem points in 1990 as a reference, the target is that in 2000 approximately 40% and in 2010 approximately 90% are solved. In 1995, 23% was solved and in 1996 29% (Fig. 3). "Solved" means only that measures are taken, varying per problem point from 0 (= nothing done) to 1 (= all planned measures are realized with proven use) and some values between.

## CONCLUSIONS

From the process described, some conclusions can be drawn:

- defragmentation by infrastructure is the responsibility of the road administration involved;
- it is very difficult to avoid new fragmentation by roads, more effort is necessary;
- procedures for taking measures are working and become a standard feature;
- many measures realized along roads are used well;
- improvement of measures is desirable;
- more effort is required for measures along provincial and local roads;
- communication and information geared to all participants is necessary;
- many disciplines are involved and must join forces.

Habitat fragmentation

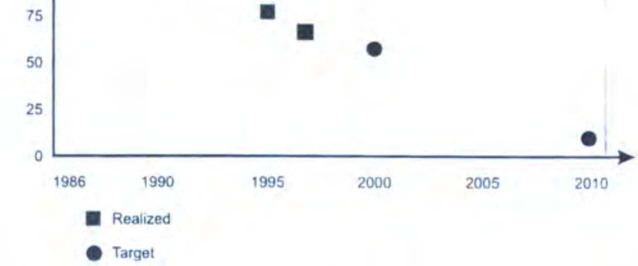



Fig. 3. Progress in solving problem points between national ecological network and main infrastructure network. The number of problem points in 1990 is indicated by 100.

## REFERENCES

Bekker, G.J. 1989. Faunavoorzieningen bij wegen. Wegen, 63(12/1): 8–13.

Bekker, G.J. 1996. RWS ontsnippert de snippers langs rijkswegen. Otar, 81(12): 443–449

Bekker, G.J. and K.J. Canters. 1997. The continuing story of the badgers and their tunnels. In: Proceedings of the International Symposium on Habitat Fragmentation and Infrastructure. Maastricht, Delft, The Netherlands.

Bekker, G.J. 1997. Passage van rijkswegen via grote faunatunnels. In preparation.

Canters, K.J. and R. Cuperus. 1997. Fragmentation of bird and mammal habitats by roads and traffic in transport regions. In: Proceedings of the International Symposium on Habitat Fragmentation and Infrastructure. Maastricht, Delft, The Netherlands.

Derckx, H. 1984. Eerste evaluatierapport van toestand en gebruik van dassenvoorzieningen rijksweg 73, baanvak Teerschdijk–Maasbrug. Vereniging Das en Boom. 10.

Groot Bruinderink, G.W.T.A. and E. Hazebroek. 1996. Ungulate traffic collisions in Europe. Conservation Biology, 10(4): 1059–1067.

Janssen, A. 1995. Dassentunnels onder de loep; wat er mis kan gaan en hoe het beter kan. Report 200 Wetenschapswinkel Katholieke Universiteit Nijmegen.

Keller, V. and H.P. Pfister. 1996. Bio-ökologische Wirksamkeit von Grünbrücken über Verkehrswege. Karlsruhe Veröff. PAÖ, 16: 187–193.

Kirby, K.J. 1997. Habitat fragmentation and infrastructure: perceptions of the problems and the research needed. In: Proceedings of the International Symposium on Habitat Fragmentation and Infrastructure. Maastricht, Delft, The Netherlands.

Linden, P. van der. 1994. Een wal van stobben als migratieroute. Zoogdier, 5(4): 7–11

Litjens, B.E.J. 1991. Evaluatie Wildviaducten A-50. Consulentschap Natuur, Milieu en Faunabeheer. Arnhem, The Netheerlands.

Ministere de l'Equipement et de l'Environnement. 1993. Passages pour la grande faune. Guide technique.

Ministry of Agriculture, Nature and Fisheries. 1990. Nature Policy Plan of the Netherlands. The Hague, The Netherlands.

Ministery of Agriculture, Nature and Fisheries. 1993. Green Space Structure Plan. The Hague. The Netherlands.

Ministry of Transport, Public Works and Water Management. 1990. Second Transport Structure Plan. The Hague, The Netherlands.

Miljoministeriet Danmark. 1993. Faunapassager i forbindelse med storre vejanlaeg. II faglig rapport fra DMU, no. 82.

Mulder J.L. 1996. Egels en auto's, een literatuurstudie. RWS/DWW & VZZ. Project report no. 27.

Nieuwenhuizen, W. and R.C. van Apeldoorn. 1995. Mammal use of fauna passages on national road A1 at Oldenzaal; Road and Hydraulic Engineering Division no. 22A. DLO Institute for Forestry and Nature Research; Delft/Wageningen, The Netherlands.

Nieuwenhuizen, W. and R.C. van Apeldoorn. 1995. De mogelijke verstoring van eekhoorns door verkeer: een oriënterend onderzoek; RWS/DWW & DLO-IBN. Project report no. 25.

Olbrich, P. 1984. Untersuchung der Wirksamkeit von Wildwarnreflektoren und der Eignung von Wilddurchlassen. Zeitschrift Jagd Wissenschaften, 30: 101–116.

Piepers, A.A.G. and G.J. Bekker. 1993. Mitigating habitat fragmentation due to road infrastructure in the Netherlands. In: Proceedings of the Fifth International Symposium on Environmental Concerns in Right-of-Way Management.

Reijnen, M.J.J.M., G. Veenbaas and R.B.P. Foppen. 1992. Predicting the impact of motorway traffic on breeding bird populations. Road and Hydraulic Engineering Division, DLO Institute for Forestry and Nature Research, Delft/Wageningen, The Netherlands.

Rijkswaterstaat. 1990. Cursus Natuurtechnisch Ontwerpen in de Wegenbouw. Dienst Weg- en Waterbouwkunde en Dienst Landinrichting. Delft, The Netherlands.

Rijkswaterstaat. 1993. Projectplan versnipperd ... ontsnipperd. Dienst Weg- en Waterbouwkunde. Delft, The Netherlands.

Rijkswaterstaat – Dienst Weg- en Waterbouwkunde, Dienst Landinrichting en Buro Faunatechniek Oord. 1995. Handreiking maatregelen voor de fauna langs weg en water. Delft, The Netherlands.

Sips, H.J.J. 1994. Bestaande faunapassages van de rijksweg A7 in het Robbenoordbos. Report 94.34, Bureau Waardenburg, Culemborg, The Netherlands.

Tempel, van der R. 1993. Vogelslachtoffers in het wegverkeer. Vogelbescherming Nederland en Dienst Weg- en Waterbouwkunde. Technisch rapport 11. Zeist/Delft, The Netherlands.

Verkaar, H.J. and G.J. Bekker. 1991. The significance of migration to the ecological quality of civil engineering works and their surroundings. In: Nature Engineering and Civil Engineering Works. P. Aanen et al., eds. Road and Hydraulic Engineering Division, Delft, The Netherlands.

Wiertz, J. 1991. De dassenpopulatie in Nederland 1960–1990. RIN 91/6, Leersum, The Netherlands.

Vos, C.C. and J.P. Chardon, 1994. Herpetofauna en verkeerswegen, een literatuurstudie. RWS/DWW & IBN/DLO. Project report no. 24.

Ward, A.B. 1996. Otter *Lutra lutra* mortality in relation to traffic, and experiences with newly established fauna passages at existing road bridges. Lutra, 39: 76–89.

---

### *BIOGRAPHICAL SKETCH*

***Gerardus Johannes Bekker (Hans)***

*Ministry of Transport, Public Works and Water Management, Rijkswaterstaat, Road and Hydraulic Engineering Division, Postbus 5044, 2600 GA Delft, The Netherlands*

Hans Bekker is programme manager Habitat Defragmentation in the Road and Hydraulic Engineering Division in Delft, The Netherlands. This division is an inside advisory unit of the Rijkswaterstaat, part of the Ministry of Transport, Public Works and Water Management. The task of the programme is to realize and implement the goals and targets in the Second Transport Structure Plan about habitat fragmentation caused by infrastructure. Hans Bekker is a nature engineer and specializes in bridging the gap between civil engineers and ecologists.

# The Conservation of Threatened or Vulnerable Plant Species: The Des Cantons-Lévis Transmission Line Experience

**Céline Belzile and Clarisse Cohen**

In 1994, Hydro-Québec was authorized by governmental decree to implement a new 735-kV transmission line as well as a new substation. The 181-km line, called Des Cantons-Lévis, is now under construction in southern Québec and will be completed in 1997. The line crosses large agricultural and forested private lands. As a condition of the governmental decree, Hydro-Québec had to address the issue of plant species susceptible of being designated threatened or vulnerable by law. A complete conservation program, including rare plant inventory, mitigation measures and systematic monitoring, has been planned and implemented by Hydro-Québec's environment specialists. From 1994 to 1998, this program will cover all line implementation activities, from the initial deforestation to the right-of-way landscape development and maintenance. Five species susceptible of being designated threatened or vulnerable have been discovered in the future line right-of-way. One species, wild leek (*Allium tricoccum*), designated vulnerable in 1995, has been inventoried in many sites along the line route. Mitigation measures have been developed for 14 populations of these species and mainly consisted in preserving the plants natural habitat by special deforestation methods. From 1995 to 1998, an annual monitoring assesses the actual impacts of the Des Cantons-Lévis transmission line on these plant populations and evaluates the effectiveness of the mitigation measures.

*Keywords*: Hydro-Québec, Des Cantons-Lévis, transmission line, threatened species, vulnerable species, rare plant, mitigation measure, environmental monitoring, conservation

## INTRODUCTION

In 1994, Hydro-Québec was authorized by governmental decree to build a new transmission line in southern Québec. The project, called Des Cantons-Lévis, consisted in implementing a 181-km line that connected two existing substations. A new 735-230-kV substation, named des Appalaches was also built (Fig. 1). In order to minimize right-of-way deforestation, the selected line route is partly implemented in an existing line's right-of-way of lower voltage (230 kV) that is to be dismantled. The construction of the Des Cantons-Lévis line started in 1994 and will be completed by the end of 1997 (Table 1). Activities causing the most important impacts on rare plant populations were initial deforestation and landscape development of the right-of-way. The latter consists of soil uprooting and levelling, and then sowing of grasses to control vegetation growth. Landscape development would facilitate right-of-way maintenance and, in some cases, would allow agriculture.

Before governmental authorization, environmental impact assessment studies, as per Section 31.1 of the Québec Environmental Quality Act, were carried out, from 1989 to 1991 (Hydro-Québec 1991a). At that time, rare plant species conservation was not yet an important issue and the subject was just briefly mentioned in these studies. However, in the legal and administrative context of the mid-90s regarding threatened or vulnerable species, the government of Québec asked Hydro-Québec to address the issue of rare plants along its selected line route.

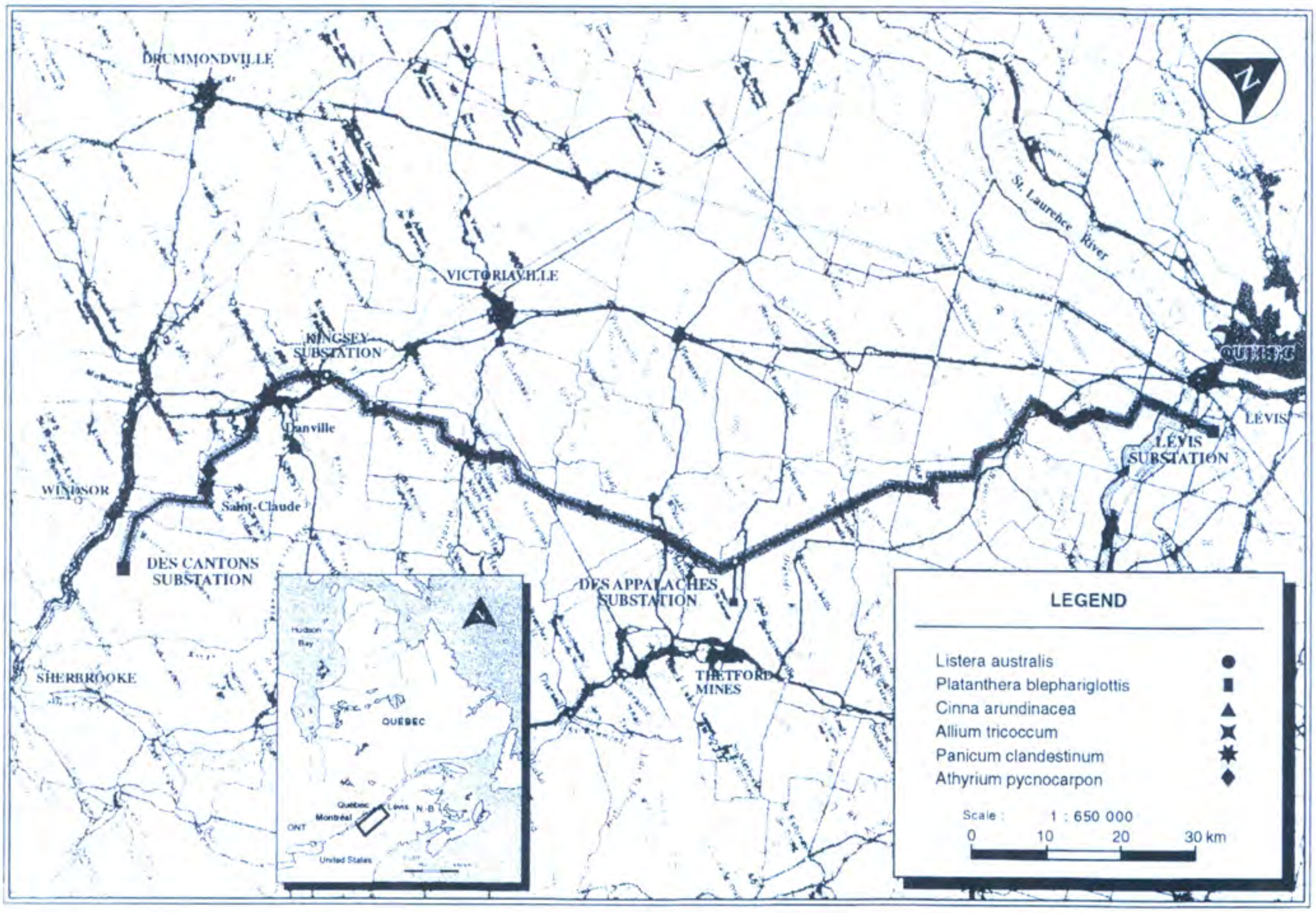



Fig. 1. Location of the des Canton-Lévis Transmission Line and of the rare plant populations.

**Table 1. The Des Cantons-Lévis project schedule**

| | |
|---|---|
| Environmental impact assessment studies | 1989–1991 |
| Governmental decree | 1994 |
| Right-of-way deforestation | 1994–1995 |
| Line construction | 1994–1996 |
| Right-of-way landscape development | 1996–1997 |
| Operation and maintenance | from 1997 |

In fact, in 1989, the province of Québec adopted an Act regarding threatened or vulnerable species, in order to preserve the biodiversity of Québec wild species, both fauna and flora. In 1992, in order to implement this legislation, the Québec Ministry of Environment and Fauna published a Policy for the protection and management of threatened or vulnerable species. For the flora, a list of 374 species susceptible of becoming designated threatened or vulnerable by law was released (Ministry of Environment and Fauna 1992, Lavoie 1992). In this Policy, threatened species are defined as all species for which extinction is apprehended. For vulnerable species, survival is precarious but extinction is not yet apprehended.

In order to address the new problematic of rare plant species and to respond to the governmental decree, Hydro-Québec elaborated a specific approach targeting the following objectives:

- to identify the presence of vascular plants susceptible to be designated threatened or vulnerable along the Des Cantons-Lévis line route,
- to develop mitigation measures for protecting plant populations affected by the transmission line,
- to put in place an environmental surveillance plan,
- to elaborate a monitoring program.

## OBJECTIVES

The main purpose of this paper is to explain how Hydro-Québec addressed the issue of threatened or vulnerable plant species in the Des Cantons-Lévis project. It presents the different phases of the approach and more specifically: (a) the results of the rare plants inventory, conducted in 1994; (b) the mitigation measures designed to protect rare plant populations affected by the line; and (c) the four-year monitoring program. Some preliminary results of this monitoring are also briefly presented.

## THREATENED OR VULNERABLE PLANTS INVENTORY

### Study area

The study area for threatened or vulnerable plants inventory included the 181-km long selected line route, covering the complete 80-m wide right-of-way and its immediate surroundings. The geological formation of the whole study area belongs to the Appalachian formations which are characterized by a broad mineralogic diversity. On a bioclimatic aspect, all the study area is located in the temperate zone dominated by deciduous forests. The climax vegetation is the Laurentian or linden maple forests (Thibault and Hotte 1985). Most of the plant species of the study area are temperate North-American or temperate eastern North American species. These species are at the northern limit of their spatial distribution in southern Québec, at the level of the Appalachians and of the St. Lawrence Valley.

### Inventory method

The inventory method consisted in identifying only the potential habitats for rare plant species that would then be visited in the field (FORAMEC Inc. 1994). First, a list of 93 species susceptible of being found in the line's right-of-way was established. It was based on the Ministry of Environment and Fauna's list of the 374 plants susceptible of being designated by regulation as threatened or vulnerable. Different herbaria were also consulted to find detailed information on rare plants spatial distribution and habitats. From this list, it was then possible to determine the potential habitats that should be considered for field inventory. For the Des Cantons-Lévis project, these habitats were: stable opened habitats, riparian habitats, wetlands, rocky habitats, and mature maple forests. On the 181 km of the line, 37 km were inventoried in the field as potential habitats and 14 water courses were visited. A transect method was used to survey all potential habitats. These transects were parallel to the right-of-way and covered the whole cleared area. A first inventory was conducted between the end of June and the middle of July 1994 for wetlands and maple forests; a second one was undertaken between the end of August and the middle of September 1994, mainly for riparian habitats. This schedule was based on species' phenology.

Six rare or vulnerable species have been identified in the right-of-way. One species, wild leek (*Allium tricoccum* Ait.) was designated vulnerable by regulation in 1995. The five other species are susceptible of being designated threatened or vulnerable. These are two weeds, Reed Cinna (*Cinna arundinacea*) and Corn Grass (*Panicum clandestinum*), two orchids *Platanthera blephariglottis* (Willd.) Lindl. (syn. *Habenaria blephariglottis*) and *Listera australis*, and a fern *Athyrium pycnocarpon*. They are distributed along the line route in 14 distinct populations (Fig. 1). Eleven of these were unrecorded populations and the inventory contributed to enhance the provincial Ministry of Environment and Fauna database on rare plants (Naturel Heritage Data Center). Specimens were donated to three herbaria.

### The species

Six populations of *A. tricoccum* were found in maple forests that were partly deforestated to implement the Des Cantons-Lévis transmission line. *A. tricoccum* is a spring ephemeral of eastern North American deciduous forests. In southern Québec, the wild leek is at the northern limit of its distribution. Since 1995, the species is protected legally and commercial sale is forbidden.

One population of *C. arundinacea* was found in the existing right-of-way and in the surrounding habitat, an open silver maple forest in the flood plain of the Bécancour River. It is a tall perennial weed, growing in humid wooded areas or marshes.

The two populations of *P. clandestinum* were found in riparian habitats of two different rivers. These populations grow in the existing right-of-way that was widened to implement the Des Cantons-Lévis transmission line.

Four small but distinct populations of *L. australis* were discovered in the right-of-way and its surroundings, at the edge of a rich and undisturbed peat bog. *L. australis* is a small and very discreet perennial. Its photosynthetic season is short, ending at the end of June. This orchid is known in only a few locations in eastern Canada and it is considered rare by Argus and Pryer (1990).

*P. blephariglottis* was found in mid-July, in two large populations ($N > 5{,}000$) in the same peat bog where *L. australis* was found, but in more open sites.

Finally, one population of the fern *A. pycnocarpon* was discovered in a small shrubby area surrounded by a mature maple forest. This species reaches the northeastern limit of its distribution in the province of Québec.

## MITIGATION MEASURES

Rare plant habitats were preserved in as much of a natural state as possible by special deforestation methods whenever it was possible without compromising the safety of the line. In the field, each population's area was flagged and signs were posted indicating the type of clearing to be applied. Habitat protection was possible for all three weeds populations of *C. arundinacea* and *P. clandestinum*. An initial deforestation method C was used in the sensitive riparian habitats sheltering these species. This method calls for manual cutting only of trees that are incompatible with the transmission line. The use of any machinery is prohibited (Hydro-Québec 1991b). Deforestation method C applies to sensitive areas where cutting has a major environmental impact.

**Table 2. Mitigation measures for protecting threatened or vulnerable plant populations along the Des Cantons-Lévis transmission line**

| Rare or vulnerable plant population | Mitigation measures |
|---|---|
| *Cinna arundinacea* – Bécancour River | – Initial deforestation method C protecting the riparian habitat<br>– No work area on the river shores |
| *Panicum clandestinum* – Nicolet River – Stoke River | – Initial deforestation method C protecting the riparian habitat<br>– No work area on the river shores |
| *Listera australis* *Platanthera blephariglottis* (in the existing right-of-way) | – Initial deforestation method B<br>– Construction works on geotextile<br>– Machinery must travel only in the access road (8 m wide) |
| *Listera australis* *Platanthera blephariglottis* (in the new right-of-way) | – Construction works in winter<br>– Initial deforestation method B<br>– Bypass of the peat bog by the machinery |
| *Athyrium pycnocarpon* – St. Claude | – Initial deforestation method B protecting the whole population<br>– Siting of the access road to avoid the population |
| *Allium tricoccum* – St. Claude | – Initial deforestation method B<br>– Partial relocation of the population outside the right-of-way |
| *Allium tricoccum* – St. Julien | – Initial deforestation method B |
| *Allium tricoccum* – Tingwick – Chesterville – Danville – Landry River | – No mitigation measure for populations in the right-of-way<br>– Edge-effect study for populations outside the right-of-way |

Conservation of *L. australis* and *P. blephariglottis* peat bog habitat was possible by applying an initial deforestation method B. Under this method, all trees are cut down (all species up to 3 m in height at maturity) but the shrubby stratum is preserved along with the stumps and root systems of the trees cut (Hydro-Québec 1991b). This deforestation method was also applied to the location of two populations of *A. tricoccum* and to the fern population *A. pycnocarpon*.

**Table 3. Relocation sites of wild leek outside the Des Cantons-Lévis transmission line in 1996**

| Site | No. of clumps | No. of bulbs | No. of scapes | No. of seeds | No. of germinated seeds |
|---|---|---|---|---|---|
| 1 | 30 | 221 | 48 | 125 | 100 |
| 2 | 30 | 279 | 49 | 127 | 100 |
| 3 | 11 | 102 | 22 | 126 | 100 |
| 4 | 30 | 379 | 124 | 100 | 0 |
| Total | 101 | 981 | 243 | 478 | 300 |

In the case of four populations of *A. tricoccum*, other large populations were found outside the Des Cantons-Lévis right-of-way, insuring the survival of the species in the area. In fact, the size of these populations was over the minimum viable, which is established to 1,000 plants for this species. For populations located in the right-of-way, and although the initial deforestation was causing their disappearance, no mitigation measures were applied because the perennation of the species was not compromised. The mitigation measures elaborated for each of the 14 rare or vulnerable plant populations are presented in Table 2.

### *A. tricoccum* relocation

Using one of the *A. tricoccum* populations, an experiment of relocation was initiated, in collaboration with Dr. Andrée Nault, botanist at the Montréal Biodôme, a research and education center. Transplantation of *A. tricoccum* bulbs was carried out during the fall seasons of 1995 and 1996. The main objective was to develop a rescuing method for wild leek when its habitat destruction was inevitable. A total of 981 bulbs of *A. tricoccum* were removed from the maple forest before its deforestation. They were then transplanted in a similar habitat nearby, outside the right-of-way. In addition to the transplanted bulbs, 478 seeds were collected *in situ* from the scapes and sown as well as 300 germinated seeds obtained from Dr. Nault (Table 3).

## MONITORING PROGRAM

A four-year monitoring program was elaborated and implemented by a team of Hydro-Québec's biologists. The monitoring started in June 1995 and will continue until 1998.

### Monitoring objectives

The goals of the monitoring program are to determine the actual impacts of the Des Cantons-Lévis transmission line on the 14 rare or vulnerable plant populations and to assess the effectiveness of the mitigation measures. As the last step of the environmental impact assessment process, the monitoring provides for its continuous improvement by integrating the results of both observations *in situ* and theoretical research.

## Monitoring method

These objectives are achieved by assessing the evolution of each plant population located in and near the right-of-way, in terms of stability, growth or decline. Based on the species' phenology, a follow-up schedule was elaborated for the four main activities of the Des Cantons-Lévis line's implementation, which are deforestation, construction, right-of-way landscape development and maintenance. For *C. arundinacea, P. clandestinum, L. australis, P. blephariglottis* and *A. pycnocarpon*, each population is visited once a year, at the flowering or reproductive period. *A.tricoccum* populations are visited twice a year: in mid-May, during full foliage emergence, for population estimation, and at the end of August, during seed production, for assessing the sexual reproductive effort. During the four-year monitoring program, the evolution of each population is followed by counting up all individual plant or, when density is too high, by sup-sampling the population in 1 $m^2$ plots. Habitats are described using vegetation cover and dominant plant species.

## Some preliminary results of the monitoring

The first two years (1995 and 1996) of the monitoring program have mainly consisted in: describing each plant population in terms of number of individuals and habitat; searching for other populations outside the Des Cantons-Lévis right-of-way; and carrying out the relocation of *A. tricoccum*. Moreover, after discussion on the impacts of ecosystem fragmentation, a new research objective was added to the initial monitoring program. It consists in assessing the impact of the right-of-way on *A. tricoccum* populations at the edge between remnant deciduous forests and the developed right-of-way. Although it is too soon to predict the trends of the 14 rare or vulnerable plants populations, some field observations can already be presented. The change in the number of populations, from 1994 to 1996, is summarized in Table 4.

*1995 Preliminary results*

Of the eight initial populations of species susceptible of being designated threatened or vulnerable located in 1994, five survived in 1995. Two very small populations of *L. australis* ($N_1 = 1$, $N_2 = 2$), found in 1994 in the right-of-way, disappeared probably due to the passage of heavy machinery. One of the two populations of *P. clandestinum* ($N = 10$) also disappeared in 1995 although no construction work had begun. However, three new populations were found: two populations of *L. australis* ($N = 16$) and one population of *P. blephariglottis* ($N = 100$). Thus, in 1995, there were still eight rare plant populations. For *A. tricoccum*, due to the 1994 inventory date, the existence of all six populations was based on the observation of scapes, which is not a good indicator. In fact, in this species, the proportion of mature ramets bearing scapes shows important annual fluctuations and, in some poor reproductive years, only a few percent of large ramets produced a scape. For example, Nault and Gagnon (1993) observed that, in 1984, 48% of large ramets produced a scape compared to only 4% in 1985. In 1995, five of the six *A. tricoccum*'s populations affected by the Des Cantons-Lévis transmission line had sexual reproduction (presence of scapes with seeds). Thus, in 1995, the presence of 13 rare or vulnerable plants populations was confirmed, three of them being new ones and four having disappeared during initial deforestation and construction activities.

*1996 Preliminary results*

In 1996, during the construction of the Des Cantons-Lévis transmission line, all 14 populations originally found in 1994 where visited as well as the additional orchid populations discovered in 1995. This time, the presence of only five of the eight rare plant populations was confirmed. All six *A. tricoccum* populations were present, although one of them was in serious decline

**Table 4. Number of rare or vulnerable plant populations in the Des Cantons-Lévis Right-of-Way from 1994 to 1996**

| Species | Number of populations | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1994 Inventory | 1995 Monitoring | | | 1996 Monitoring | | |
| | | Existing pop. | New pop. | Total | Existing pop. | New pop. | Total |
| *Cinna arundinacea* | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| *Panicum clandestinum* | 2 | 1 | 0 | 1 | 1 | 0 | 1 |
| *Listera australis* | 2 | 0 | 2 | 2 | 0 | 0 | 0 |
| *Platanthera blephariglottis* | 2 | 2 | 1 | 3 | 2 | 0 | 2 |
| *Athyrium pycnocarpon* | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| *Allium tricoccum* | 6 | 5 | 0 | 5 | 6 | 0 | 6 |
| Total | 14 | 10 | 3 | 13 | 11 | 0 | 11 |

after the passing of heavy machinery for the right-of-way deforestation. As for 1995, the *P. clandestinum* population of the Stoke River site was still not found in 1996. In that year, the orchid populations were severely threatened by the drainage of their habitat, originally a rich and undisturbed peat bog. This drainage was made by the owner of the lands on which Hydro-Québec has only the right-of-way. All four populations of *L. australis*, the rarest species found in this project, disappeared. The largest population of *P. blephariglottis* is still existing but observations in the field showed a perceptible decline. In the long term, the survival of this population seems compromised. However, other species, and especially the two weeds, are showing good population growth. Thus, in 1996, 11 rare or vulnerable plant populations were still present.

The 1996 monitoring has allowed a more precise estimation of the populations of *A. tricoccum* in and outside the right-of-way, by visiting them in the spring, during the emergence of the leaves when ramets can be counted. This precise counting was necessary to follow the evolution of the two populations located entirely in the right-of-way, where a clearing "method B" (preservation of the shrub layer) was applied. It was interesting to note, that in 1996, two years after the initial deforestation, one *A.tricoccum* population (St. Julien site) was still present in large number ($N > 6\,000$) in the right-of-way. On the other hand, the second population (St. Claude site) had almost disappeared the first year because the deforestation method preserving the shrubby stratum was not correctly applied.

## CONCLUSION

The Des Cantons-Lévis project was the first transmission line in southern Québec where the issue of rare plant conservation had to be addressed. Although the project was implemented in agricultural and agroforested private lands, there was a high probability of finding plant species susceptible of being designated threatened or vulnerable by law. In fact, of the 93 species that could possibly be present in the study area, six species have been discovered. They are distributed along the line route in 14 separate populations.

To protect these rare plant populations, Hydro-Québec environment specialists adapted existing mitigation measures and elaborated new ones. It was assumed that the implementation of these measures would insure the existence of rare or vulnerable plant populations. However, by its novelty, the issue of rare or vulnerable plants conservation had to be well documented and the assumptions on the actual impact of the project and on the effectiveness of the mitigation measures had to be demonstrated. A four-year monitoring program was therefore put in place by Hydro-Québec. After the first two years, many data had been collected and analyzed. It is still too soon, however, to determine the trends in the rare or vulnerable plant populations. The issue of integrating development activities along with biodiversity conservation is in continuous evolution. The Des Cantons-Lévis transmission line experience allowed Hydro-Québec to participate in the effort and reflection on this major environmental challenge.

## ACKNOWLEDGEMENTS

We are grateful to Messrs Jean Deshaye and Denis Bouchard, botanists for FORAMEC Inc, for their tremendous inventory work and their help at the beginning of the monitoring program. We thank Dr. Andrée Nault and Mr Stephane Adams, from the Montréal Biodôme, for their collaboration in the wild leek relocation experiment. We gratefully acknowledge the help of Mrs Marie-Josée Grimard, graduate student at the Université du Québec à Montréal, who has greatly contributed to the study.

## REFERENCES

Argus G.W. and K.M. Pryer. 1990. Les plantes vasculaires rares du Canada. Musée canadien de la nature, Ottawa. 192 p.

Belzile, C. and C. Cohen. 1995. Suivi environnemental 1995 des plantes vasculaires vulnérables ou susceptibles d'êtres désignées menacées ou vulnérables. Ligne à 735 kV Des Cantons-Lévis. Hydro-Québec, service Études environnementales. 36 p.

Cole, F.R. and D.H. Firmage. 1984. The floral ecology of *Platanthera blephariglottis*. American Journal of Botany, 71(5): 700–710.

Falk, D.A. 1992. From conservation biology to conservation practice: strategies for protecting plant diversity. In: Conservation Biology. P.L. Fiedler and S.K. Jain, eds. Chapman & Hall, New York. pp. 397–431.

FORAMEC Inc. 1995. Suivi environnemental des plantes vasculaires susceptibles d'être désignées menacées ou vulnérables. Ligne à 735 kV Des Cantons-Lévis. Rapport complémentaire pour le service Études environnementales, Hydro-Québec. 17 p.

FORAMEC Inc. 1994. Ligne à 735 kV Des Cantons-Lévis. Inventaire des plantes vasculaires susceptibles d'être désignées menacées ou vulnérables. Rapport pour la vice-présidence Ingénierie, Hydro-Québec. 32 p.

Hydro-Québec. 1991a. Rapport d'avant-projet. Ligne à 735 kV Des Cantons-Lévis et poste Appalaches à 735-230 kV. Volumes 1 to 6.

Hydro-Québec. 1991b. Environment Code. 241 p.

Lavoie, G. 1992. Plantes vasculaires susceptibles d'être désignées menacées ou vulnérables au Québec. Direction de la conservation et du patrimoine écologique, ministère de l'Environnement et de la Faune, Québec. 180 p.

Marie-Victorin, F. 1964. Flore Laurentienne. 2nd edn. Presses de l'Université de Montréal, Montréal. 925 p.

Ministère de l'Environnement et de la Faune du Québec. 1992. Politique québécoise sur les espèces menacées ou vulnérables. La désignation. 27 p.

Nault, A. and D. Gagnon. 1993. Ramet demography of *Allium tricoccum*, a spring ephemeral, perennial forest herb. Journal of Ecology, 81(1): 101–119.

Saunders, D.A., R.J. Hobbs and C.R. Margules. 1990. Biological consequences of ecosystem fragmentation: a review. Conservation Biology, 5(1): 18–32.

Thibault, M. and D. Hotte.1985. Les régions écologiques du Québec méridional. Carte à 1:1 250 000 (2e approximation). Ministère de l'Énergie et des Ressources, Québec, Canada.

## *BIOGRAPHICAL SKETCHES*

***Céline Belzile***

*Hydro-Québec, Service Études environnementales, 800 Boul. de Maisonneuve est, 19th floor, Montréal, Québec, Canada, H2L 4M8*

Céline Belzile is a biologist, graduated from Université du Québec à Montréal (Québec). She obtained a Master in Environmental Studies from York University (Ontario). She has been involved with environmental and scientific organizations and, since 1990, she has been working for Hydro-Québec, specializing in environmental impact assessment studies.

***Clarisse Cohen***

*2 440 Valade Street, Ville Saint-Laurent, Québec, Canada, H4M 1N3*

Clarisse Cohen attended McGill University (Montréal, Québec) and graduated in biology. She went to graduate school at Université de Montréal, École Polytechnique (Québec) in Environment. Since then, she has been working in the environment field for almost 10 years, first in the private sector for environment consultant firms, and later as an environmental advisor for Hydro-Québec specializing in environmental impact assessment studies.

# Implementing The National Protocol System Down-Under: Cooperative Management Device for Biodiversity Conservation on Road Corridors in Australia

**Quentin Farmar-Bowers**

The paper reviews the importance of road corridors for biodiversity conservation in Australia and describes progress in developing and implementing a new management device for the conservation of biodiversity on road corridors. The new device is called the National Protocol System (NPS). The NPS is a formal cooperative management system involving all stakeholders. Stakeholders are defined. The main uses of the NPS are described and its three fundamental flaws are discussed. The paper describes progress with the NPS in the last year and some of the proposals to promote and develop the system in the coming year. The paper concludes that the features of the NPS would make it an effective and efficient management device but that it may be too far ahead of current management capabilities to be readily accepted by current managers.

*Keywords*: Australia, biodiversity, highway corridors, cooperative management, stakeholders, sustainable development

## INTRODUCTION

### A huge area

There are about 800,000 km of roads in Australia and many other linear corridors for transmission lines, pipelines, rail ways and stock routes[1]. Most of these linear reserves were established before the adjacent land was used for agriculture, grazing, forestry, urban-residential and industry. Consequently these linear reserves have a duel role in the conservation of biodiversity in Australia.

*Role One* (an opportunity to conserve biodiversity): In areas that have been cleared during European settlement, the linear reserve may contain the only remnant of the original native vegetation (Saunders and Hobbs 1991). Roads were set out throughout Australia, every region has them. Consequently we could view road reserves (which are public land) as Australia's most diverse but least protected biodiversity reserve.

*Role Two* (an opportunity to reduce the impacts of road use and construction on biodiversity): Construction and maintenance of the transport facilities within the reserves damages the remnant vegetation on the reserve and also impacts adjacent ecosystems. Drainage of roads is especially significant in damaging adjacent ecosystems in Australia (McRobert 1996).

### Numerous stakeholders

Road reserves are used by a number of agencies and individual other than the road authority. Three groups have an interest; first, the adjacent landowner, mainly farmers and graziers; second, the utilities, such as electricity, water and telephone companies; third, the conservation agencies, conservation groups, universities and individual professionals. In this paper all three groups are referred to as *stakeholders*.

### Current environmental management

Agencies and utilities companies look after their own environmental affairs. Large construction jobs are sometimes subjected to an environmental impact state-

1 This paper relates to road reserves although the National Protocol System would be a useful management system in every linear reserve (including river frontages) where a number of stakeholders are involved.

ment (EIS) and review. The environmental objective of the EIS, which is done by the proponent, is to reduce the impact of the proposed work. There tends to be little formal review of day to day management activities and therefore long-standing maintenance practices rarely change.

Environmental managers are focused on reducing the environmental impact of their employers' works programs. They are not employed to look at changes occurring in the landscape, especially relatively slow changes such as biodiversity decline. However, a few people in the community have pressured for this wider view to be considered. As a result, formal roadside conservation committees have been established by the bureaucracies to advise the agencies managing the road reserves (or the government ministers involved). The advisory committees in Victoria and Western Australia have been the most successful. The advisory committee in New South Wales is about two years old.

### Are current management arrangements adequate for biodiversity conservation?

Biodiversity conservation has not been a focus for road reserves. Nobody is to blame but unfortunately wider issues such as biodiversity conservation, are falling between the cracks. Biodiversity conservation has been occurring more by luck than by design.

If all the stakeholders really wanted to conserve biodiversity, conservation would occur. However biodiversity is not a corporate objective for most stakeholders. It is something new. The stakeholders who use the road reserves for utilities such as road pavements and electricity lines, have not had to focus on biodiversity conservation. Even environmental specialists have not had this focus directly.

The author thinks that development and maintenance of transport infrastructures and other uses of the road reserve is leading to a significant decline in the value of these linear reserves for biodiversity conservation, and that the current management arrangements, even if applied more energetically, are inadequate for achieving 100% biodiversity conservation. Better arrangements are needed.

## BACKGROUND

### Three reasons for taking conservation action on highways corridors now

(1) Legal reasons: There is a increasing range of environmental legislation in Australia and it appears that many stakeholders are unaware of the extent of their legal responsibilities (Bates in press).

(2) Political importance of biodiversity: The maintenance of biodiversity is one of the three objectives of the Australian National Strategy for Ecologically Sustainable Development (Commonwealth of Australia 1992). It is part of the Inter-governmental Agreement on the Environment (COAG 1992) and there is a National Biodiversity Strategy (Commonwealth of Australia 1996). Australia is also a signatory to the International Convention on the Conservation of Biodiversity (UNEP 1992). Therefore, politically at least, the maintenance of biodiversity is important in Australia.

The significance of biodiversity conservation has also been recognised by the road industry (Austroads 1994, 1995).

(3) The value of biodiversity to Society is being recognised by the public (as part of Australia's Social Capital): Although industries are busy cashing in this particular social capital to gain cheaper roads and cheaper road management. The rhetoric is about conserving *our native heritage* but actions include *development, clearing, ploughing and grazing*, not *maintenance, learning and appreciation* of biodiversity.

Australians are becoming more interested in biodiversity conservation and its value and international literature is having an impact (Beatie 1995, Commonwealth of Australia 1993, Houston 1994, Patrick 1997). Conserving biodiversity is being appreciated as an inter-generational equity issue (Farmar-Bowers and Ward 1995). The mismatch between the overall value of the biodiversity resource (very high) and the overall effort going into maintaining that resource (very small) is becoming a issue.

Biodiversity conservation is small in terms of overall budget in Australia. The former biodiversity unit in the Commonwealth Government of Australia had a budget of $13 million in 1995/6 financial year, about the same as the Governor General (the Queen's representative in Australia). The current picture is confusing although it appears that the budget for conservation is on the increase.

### Three issues to make conservation on highways corridors effective

(1) Formal stakeholder cooperation: The work of many public utilities and individual stakeholders damage biodiversity on transport corridors. Cooperation is needed but cooperative management fails unless fair and effective arrangements are agreed at the outset. An effective arrangement would secure commitment from all Stakeholders to work together to achieve 100% biodiversity conservation. However there are plenty of reasons and opportunities to 'free load' on conservation work programs that are run cooperatively, especially for commercial stakeholders.

(2) Management assistance: Managing nearly a million kilometres of highway corridors to conserve remnants of native vegetation and wildlife in perpetuity is an immense task. Managers will need a lot of help. Not many road authority employees have the training, interest and aptitude to manage biodiversity.

New management arrangements should include mechanisms to provide mangers with knowledge and advice which is specific to sites, times and problems.

Knowing how to conserve Australia's natural environment is going to take an enormous effort and substantial resources. The knowledge needed for this does not exist in Australia yet, although there are many dedicated workers. The transport industry needs quality and reliable management information to conserve biodiversity, not the cheapest financially. In their own interests, the transportation industries should be helping to fund the growth of this knowledge in centres of specialisation.

(3) Timing: Australia needs a management system that delivers biodiversity conservation in the long term. Therefore the management system must be immune to changing personnel and organisations. It must be able to execute very long term scientific research and secure site management programs in perpetuity. It must also be fail-safe.

## NATIONAL PROTOCOL SYSTEM

### Description

The author is developing a formal cooperative management arrangement called the *National Protocol System* (NPS) under contract to Austroads. Austroads is the association of state highway authorities in Australia and Transit New Zealand.

The NPS aims to bring *all stakeholders* into a single *agreement* called the Protocol Core which contains one principal and four operational objectives and seeks their *commitment to these objectives* through documents called Protocol Chapters (Farmar-Bowers 1995a and 1996). Protocol chapters are like mini corporate plans. They tell people what the corporation is going to do in relation to conserving biodiversity during a specific period (and what it expects of employees). The protocol chapters are public documents.

The third part of the NPS is called Management Arrangements. We propose to develop pieces of management information for stakeholders that will help them implement the commitments they made in their protocol chapters. All work under this Management Arrangements banner will be funded cooperatively by stakeholders or/and government. A start has been made on this program which has been funded by Austroads.

### Six purposes for the National Protocol System

(1) The NPS provides a 'template' that road agencies and other stakeholders can adopt and develop to guide their work in roadside management. It can be used as an objective is an EMS under the ISO 14000 series.

(2) The NPS can provide a mechanism for industries, such as the transport industry, to cooperate on a national or regional scale to fund joint programs for mutual benefit. These joint programs could involve the provision of management information, research, and training to assist individual agencies to be efficient and effective in biodiversity conservation.

(3) The NPS can also protect investments in specific locations. Individual stakeholders may spend, on their own volition, money and effort in protecting particular areas of high biodiversity value. Without a formalised agreement between all stakeholders it may be impossible to prevent other stakeholders damaging these areas inadvertently in the course of their own work.

(4) The NPS could be the foundation agreement to consolidate stakeholders needs for new knowledge. Such a consolidation would encourage the development of new biodiversity conservation technologies (and businesses based on these technologies) across all industries. The conservation of biodiversity is of national and international concern and a market will develop for quality technologies. Having a management system going from early days will ensure that people can get organised quickly and develop reliable and effective technologies. The faster this happens the better since less biodiversity will be lost in the intervening years.

(5) The NPS has the potential to dramatically reduce conflict between stakeholders by providing a common focus and a mechanism for dialogue and review. The NPS opens the management of public highways to public scrutiny.

(6) The NPS provides a mechanism for sharing information and research expenditure between highway authorities and all other industries and bodies involved with conservation of biodiversity.

### The objectives of the NPS

The five objectives are set out in Table 1. Collectively the objectives are the core of the NPS.

Cooperative management involves the pooling of information and free access to it. In a cooperative system, success depends on the performance of every individual. Failure of one stakeholder to conserve biodiversity at a site would reduce the effectiveness of all stakeholders associated with that site. Small stakeholders would not be disadvantaged in the NPS as it would be in the interests of the larger stakeholders to provide information, advice and even material help to

**Table 1. The objectives of the National Protocol System**

Principal Objective of the Protocol Core (draft):

Protection of biological diversity and maintenance of ecological processes and systems on roadsides and in adjacent natural ecosystems

Operational Objectives of the Protocol Core (draft):

1. Devise and implement a cooperative management system.
2. Develop and disseminate knowledge through the cooperative management system
    - 2.1. Document roadside biodiversity
    - 2.2. Document threatening processes
    - 2.3. Improve management information.
3. Involve all stakeholders in biodiversity management decisions.
4. Establish independent stakeholder review systems.

achieve the common goal. The focus in this cooperative management system is to develop and apply knowledge to achieve long term biodiversity conservation. The greater the knowledge base and interaction between stakeholders the greater the incentives become to protect the commonly held and managed biodiversity asset. Stakeholders need each others input to make the whole system effective and efficient. The stakeholders who are involved locally (and in a small way) need the results of research and investigations that larger, nationally based stakeholders can undertake. In turn, the regionally and nationally based stakeholders need the local stakeholders to monitor site conditions and provide local knowledge.

In agreeing to these five objectives, the stakeholders need to appreciate how their unique contribution will have value in the achieving the overall objective. The commitment they make in their protocol chapter needs to be precise and achievable. It will take some iterations before this can be achieved. Stakeholders may attempt to achieve too much too soon and get discouraged. For each area some form of lead group or agency will be needed to pull the NPS into existence. This may be the state transport authority or state conservation agency. Once in existence, the system will develop its own arrangements and its own momentum.

## Protocol Chapters

Stakeholders would begin to join the NPS by preparing a Protocol Chapter setting out their agreement to the five core objectives and describing how they intend to work towards achieving the objectives. Their proposals and subsequent site work must be acceptable to their peers (other stakeholders).

Operational Objective 4, *Establish independent stakeholder review systems* is very important as it provides quality check points. Before a Protocol Chapter is accepted in a region is will have to be approved by a peer review (other Stakeholders). Some reviewers will come form different regions or different states. Once it gets past this hurdle and implemented, then its up to the local stakeholders to ensure that organisations and individuals live up to the commitments they have made in their Protocol Chapters. Getting these stakeholder review systems into operation will provide the adrenalin for the National Protocol System.

The NPS would be run, developed and reformed by stakeholders themselves. Stakeholders would agree administrative arrangements and quality control review systems that best suited them.

## Management arrangements

Once stakeholders start working on conserving biodiversity they will be faced a similar range of issues. They can use the NPS to cooperatively address these issues. It is more efficient to work together to solve common problems, than to fight over competing "solutions". It may also be more effective. To start this process going, the author has a list of items under the heading of Management Arrangements (Table 2).

The NPS could be used to organise biodiversity conservation in any situation where several stakeholders are involved and need to cooperate to be successful. For instance the NPS would be useful for managing biodiversity in wetlands and river systems (riparian lands as well as aquatic flora and fauna).

## PROGRESS TO DATE

This program commenced by the author in May 1995 in response to the Draft National Biodiversity Strategy. The NPS was devised and written up by June 1995. The NPS was workshopped during 1996 in Brisbane (Queensland) and in Hobart (Tasmania). The work-

**Table 2. Management arrangements: cooperative work under the National Protocol System**

| Item | Description | Output |
|---|---|---|
| Information system | GIS-based management information, including stakeholders' names and their Protocol Chapters | Working Document (WD): drafted |
| Jurisdiction surety | legal responsibility for biodiversity | Manual: *Environmental Law & Road Reserves*: Bates in press |
| Decision process | enhancing the human element in environmental decision making | Humphries 1996 |
| Funding | how to fund the System | |
| Getting started | understanding the NPS, warts and all | so you can explain it to others |
| Site management* | all the scientific management information we need | McRobert 1996 |

*Site management is a huge topic covering every aspect of maintaining biodiversity in perpetuity. However we are starting by looking at how roads are drained and aim to produce a manual entitled *Draining Roads and Maintaining Biodiversity* in late 1997.

shops confirmed the relevance and appropriateness of the NPS for dealing with biodiversity conservation on highways but showed that its presentation had to be improved. Unfortunately the follow through discussions and implementation were hampered by illness.

By March 1997, the program was partly back on track. By June 1997, workshops will have been held in Sydney (New South Wales), Perth (Western Australia), Hobart (Tasmania), Adelaide (South Australia) and in Cairns (Queensland). The first of the two workshop in Sydney will focus on the legal aspects of biodiversity conservation on Highways. The workshop will launch Dr Bates's Manual on environmental law which has been prepared as a contribution under the 'management arrangement' heading of the NPS. The workshop in Hobart will focus on implementing the NPS in the world heritage area in Tasmania. The Department of Transport in Tasmania are also proposing to implement the NPS in the Midlands of Tasmania by the end of 1997. These two Tasmanian trials will be partly funded by Austroads.

The additional work under 'management arrangements' is unlikely to be funded by the transport industry which is a significant set back to the program. Four studies were to be conducted and funded jointly with federal agencies and an NGO. The proposed Manual on 'Biodiversity Conservation and Road Drainage' scheduled for completion in 1997 will have to be shelved when Austroads funding ends in June 1997. Funding from Austroads for development and promotion of the NPS is also scheduled to stop in June 1997 except for the two trials in Tasmania.

Most highway agencies have programs dealing with roadside vegetation already and they increasingly contract out management and spraying programs to private firms. Down-sizing in road authorities has also reduce the time staff can have for longer term issues whatever their significance. Many agencies have taken the new emphasis on biodiversity and information on the NPS as a criticism of current vegetation control programs and have dismissed the NPS as being unnecessary even irrelevant. Apparent top level approval for biodiversity conservation and sustainable development have not translated well into actions. However the ideas in the NPS are out and getting serious consideration by many stakeholders and people interested in biodiversity conservation management.

## CONCLUSIONS

(1) There are strong and growing, legal and political reasons for road infrastructure managers to conserve biodiversity.

(2) There are also common sense reasons to conserve biodiversity (maintain Social Capital).

(3) A formal management system is required to ensure management agreements are honoured by all stakeholders.

(4) A cooperative management arrangements involving all stakeholders would be effective and may also be the most economical in the long term.

(5) The NPS is a formal cooperative management system and would be an appropriate management arrangement for biodiversity conservation on highways. However the NPS has three fundamental flaws that are inhibiting its uptake by stakeholders:

(a) Long term planning: The NPS requires long term planning. To conserve biodiversity 100% will require a fail-safe process able to survive changes in management, staff and changes in political views. It will also be dependent on the development and application of an increasing body of knowledge; long lived institutions are needed for this. Long term planning is something most of us never do. So unfortunately the NPS relies on managers having skills that hardly exist in the community.

(b) Co-operation: The NPS is all about cooperation. It is not possible for each agency involved with road reserves to develop the necessary expertise to do a decent job nor do they have the authority to make decisions stick with other stakeholders. Without cooperation and goodwill biodiversity conservation may be impossible. Cooperation at the best of times is difficult because managers have to 'give away' some of their power to the people they want to cooperate with (there has to be something in it for all parties concerned). To do this requires that the managers have to want the outcome more than they want to preserve their own status in the short term. 'Cooperation' is not a common skill in Australia and the direction being pursued in our society today is away from cooperation towards competition. Unfortunately the NPS relies for its effectiveness, on a dramatic improvement in people's ability to cooperate.

(c) Local control: Biodiversity in Australia cannot be achieved from Canberra or Sydney. It has to be achieved at a local level. A national perspective is needed but only people living nearby can monitor events, keep records and organise the unique management necessary to achieve the maintenance of biodiversity on road reserves. Local interference in highway planning for maintenance and construction is not welcomed by centralised transportation agencies. Local *consultation* is one thing, but *control* is quite another. Unfortunately the *National Protocol System* relies to a large degree, on local stakeholders to manage, monitor and organise the conservation of biodiversity (with help from specialists and information from a state or national level). It is interesting to note that *Participation* is a fundamental need for people, so allowing people to participate is a step towards achieving one of the objectives of sustainable development. Perhaps participation could be made into a sustainable development performance criteria for the transportation industry (Max-Neef 1991, Farmar-Bowers 1994).

(6) The NPS may be too far in advance of current environmental management and instead of becoming

a goal, something to go for, it may become a reason for them to withdraw. The NPS embodies the cutting edge of a number of new technologies. There is enough new technology in the NPS to put fear in even the most hardened technologist.

(7) The NPS provides a dilemma for management.

(a) Choice 1: If they apply the NPS they have to rely on three management practices that are weak or out of favour in Australia. (long term planning, cooperation and local control) and they have to forego some their discretionary power to participate in cooperation. However, if they do use the NPS, they would *still be involved* and *still be influential*. In addition they will be getting community approval for being effective.

(b) Choice 2: Alternatively, if they do not progress the NPS, biodiversity conservation will default to commercial consultants and these commercial firms will capture the knowledge base. Eventually this knowledge will ensure that the effective power will be in the hands of large consulting firms. The managers currently in power will be sidelined as 'customers'. So managers have to choose: (a) to lose some of their power now through cooperative ventures and become effective, or (b) hold onto all their power until they eventually become just *customers* and the *providers* have the real power. Choice 2 is initially more attractive but may not lead to the conservation of biodiversity; because biodiversity conservation would be the *subject* matter for the operation of the market not its *objective*. (The purpose of the market would not be biodiversity conservation.) The providers focus would be market power and profit. The customers focus would be to minimise their expense and stay in business.

(8) The NPS is less than two years old and needs to be promoted more with infrastructure managers and conservation groups. This may occur through the success of the two proposed trails in Tasmania.

(9) The work being done under management arrangements should be helpful to stakeholders even if they opt to follow their own biodiversity management arrangements.

(10) The NPS provides a contexts for many existing conservation programs. People have been able to see how their work fits into the NPS and therefore been able to relate their work to other programs.

(11) Maybe stakeholders in Australia are not yet ready for the NPS but the ideas are out and sufficient people have seen merit in them to ensure that the some form of formalised cooperative management system will continue to be discussed even though the commercial option of customers using independent consultants may be easier. The author hopes society will put conservation effectiveness before ease and profit.

## SUMMARY

A large but as yet unquantified proportion of Australia's biodiversity occurs on transport corridors. Road reserves may be Australia's most diverse but least protected biodiversity reserve. Current environmental management practices for road reserves are improving but they do not appear to have the comprehensiveness needed to achieve 100% biodiversity maintenance.

A formal cooperative management system known as the *National Protocol System* (NPS) was devised by the author in 1995. The NPS could be used by road authorities as a guide for setting up new biodiversity management arrangements that involve all stakeholders. The NPS also provides a focus for the Transport Industry to undertake joint research on biodiversity.

The NPS will be trialed in two regions by the Tasmanian Department of Transport in 1997. A number of studies addressing issue of common interest are being undertaken under the banner of *Management Arrangements* in the NPS.

The NPS has three fundamental flaws, it requires (1) long term planning, (2) cooperation and (3) gives substantial control to local people and groups. In addition it will take managers out of their comfort zones to the cutting edge of a number of technologies. The NPS may be too far ahead of current management practice and capability to be readily adopted. Relying on environmental consultants may be more attractive to road authorities than using the NPS in the short term. The ideas in the NPS have stirred considerable interest but the NPS needs to be promoted with stakeholders before it will be accepted.

## REFERENCES

AUSTROADS. 1994. Environmental strategy. Publication No. AP-27/94, Austroads, Sydney.

AUSTROADS. 1995. Strategy for ecologically sustainable development. Publication No. AP-40/95, Austroads, Sydney.

Bates, G., 1997. Environmental Law and Road Reserves. ARRB Transport Research Ltd., Melbourne. In press.

Beattie, A.J. 1995. Why Conserve Biodiversity? In: Conserving Biodiversity: Threats and Solutions, R.A. Bradstock, T.D. Auld, D.A. Keith, R.T. Kingford, D. Lunney, and D.P. Sivertsen, eds. Surrey Beatty and Sons Pty Ltd, Chipping Norton, NSW, Australia. pp. 3–10.

Commonwealth of Australia. 1992. National Strategy for Ecologically Sustainable Development, AGPS, Canberra, Australia.

Commonwealth of Australia. 1993. Biodiversity and its value. Biodiversity Series, Paper No. 1. Biodiversity Unit, Dept. of Environment Sport and Territories, Canberra, Australia.

Commonwealth of Australia. 1996. National strategy for the conservation of Australia's biological diversity. AGPS, Canberra, Australia.

Commonwealth of Australia. 1996. Reimbursing the future — An evaluation of motivational, voluntary, price-based, property-right and regulatory incentives for the conservation of biodiversity. Biodiversity Series, Paper No. 9. Biodiversity Unit, Dept. of Environment Sport and Territories, Canberra, Australia.

Council of Australian Governments. 1992. Inter-Governmental Agreement on the Environment. AGPS Press, Canberra, Australia.

Farmar-Bowers, Q. 1994. A self trainer in ecologically sustainable development analysis. Research Report ARR 257. Australian Road Research Board Ltd, Melbourne, Australia.

Farmar-Bowers, Q. 1995. Is there a road industry responsibility for biological diversity? WD RS 95/002. Australian Road Research Board Ltd, Melbourne, Australia.

Farmar-Bowers, Q. 1995a. National protocol system, biodiversity conservation on roadsides and in adjacent waterways. Sustainable Development Series TO WD 95/008. ARRB Transport Research Ltd, Melbourne, Australia.

Farmar-Bowers, Q. and Ward, B. 1995. Platypuses have power: Ecologically sustainable development and road works. Special Report 51. ARRB Transport Research, Melbourne, Australia.

Farmar-Bowers, Q. 1996. Protocol Chapters. National Protocol System. Biodiversity conservation on roadsides and in adjacent waterways. Sustainable Development Series TO WD 96/004. ARRB Transport Research Ltd, Melbourne, Australia.

Farmar-Bowers, Q. 1996a. Biodiversity and roads: Managing our journey to Mount Ararat. Proceedings of the Roads '96 Conference. Transit New Zealand, Christchurch, New Zealand. Part 6, pp. 55–70.

Huston, M.A. 1994, Biological Diversity, The Coexistence of Species on Changing Landscapes. Cambridge University Press, Cambridge, UK.

Humphries, E.S. 1996, Enhancing the human element in environmental decision making. Sustainable Development Series No. 7, TO WD 96/037. ARRB Transport Research Ltd, Melbourne, Australia.

Max-Neef, M.A. 1991. Human Scale Development, Conception, Application and Further Reflections. The Apex Press, New York and London.

McRobert, J. 1996. Background report: Road drainage and stream quality. Sustainable Development Series No. 8. TO WD 96/020. ARRB Transport Research Ltd, Melbourne, Australia.

Patrick R. 1997. Biodiversity: Why is it important? In: Biodiversity II, Understanding and Protecting Our Biological Resources. M. Reaka-Kudla, D. Wilson, and E. Wilson, eds. Joseph Henry Press, Washington, D.C.

Saunders D.A. and R.J. Hobbs (eds.), 1991, Conservation 2: The Role of Corridors. Surrey Beatty & Sons Pty Ltd, Chipping Norton, NSW, Australia.

UNEP. 1992. Convention on biological diversity. United Nations Conference on Environment and Development, No. 92-7807. Rio De Janeiro, Brazil.

---

## *BIOGRAPHICAL SKETCH*

***Quentin Farmar-Bowers***

*Principal Research Scientist, ARRB Transport Research Ltd, 500 Burwood Hwy, Vermont South, Victoria, Australia 3145*

Quentin Farmar-Bowers has qualifications in agriculture, agricultural economics and business studies. Quentin spent a few years in industry before joining the state public service in Victoria, Australia, where worked in land and natural resource policy and planning for 20 years. Quentin joined ARRB Transport Research in 1992 and has devised *Sustainable Development Analysis* and *the National Protocol System*.

# Right-of-Way Management and Habitat Fragmentation: An Integral Approach with the Spatial Concept of the Traffic Calmed Rural Area

**Catharinus Freerk (Rinus) Jaarsma and Frank van Langevelde**

Habitat fragmentation is one of the harmful effects of the road network and its traffic flows. Much attention to this problem focuses on major roads. However, the 80–90% of the overall stock representing Minor Rural Roads (MRRs) also has important impacts on species and their habitat. Growing traffic volumes increase these problems. To serve both accessibility and a sustainable environment, the spatial concept Traffic Calmed Rural Area (TCRA) is developed. This concept starts with the desired spatial function of the rural area. Besides the needs of people, the needs of nature are considered. For MRRs (the network of mainly local collector and access roads), the residence functions of the region (for inhabitants, recreationists, local flora and fauna) will be stressed, not the flow function for through traffic. The underlying idea is a clear separation between space for living and staying and space for traffic flows. The concept will result in a reorganisation of traffic flows. Present diffuse volumes at the MRRs will be concentrated at a few trunk roads. Traffic volumes and speeds within the region will decrease. In three case studies, several impacts of the TCRA (on volumes, accessibility and environment) are calculated. These cases emphasize the possibilities of the TCRA to mitigate habitat fragmentation and to enable a sustainable rural development.

*Keywords*: Habitat fragmentation, traffic calming, minor rural roads, rural traffic planning, safety, livability

## INTRODUCTION

Protection of biodiversity and sustainable development are especially important as national goals in many countries. Habitat fragmentation, to be defined as the loss and dissection of habitats and ecosystems by human activities (Canters and Cuperus 1995), is a growing problem in this context. Beside agriculture and urbanization, infrastructure and its traffic flows are principal causes of habitat fragmentation. Therefore, fragmentation effects and defragmentation measures should be considered by the right-of-way management in rural road planning. Until now, this attention focuses especially on motorways and other major roads (cf. van Bohemen 1995). However, these high quality trunk roads represent only 10 to 20 per cent of the overall stock (OECD 1986). The remainder of the network is called Low Traffic Roads or Minor Rural Roads (MRRs). It is apparent that these MRRs also have impacts on species and their habitat (van Langevelde and Jaarsma 1997).

MRRs "are mainly local collector and access roads but might also be of a higher road class" (OECD 1986). Beside these functional criteria, a volume criterion is given: daily averages up to 1,500 (in exceptional cases: 2,000) vehicles. An important traffic characteristic of MRRs is the mixed composition by mode. Heavy and light vehicles, slow and fast vehicles occur together. Also pedestrians use MRRs, for activities such as walking and jogging. By this mixed use, large differences in speeds appear, with extremes of less than 5 km $h^{-1}$ for pedestrians and up to 100 km $h^{-1}$ or even more for cars (Jaarsma and van Langevelde 1996). However, most MRRs are one lane roads with restricted pavement width. So, it is not surprisingly, that MRRs have higher accident rates (expressed in accidents per vehicle kilometre) than roads designed to carry higher volumes (OECD 1986). In The Netherlands, the accident rate on MRRs is about five times larger than on trunk roads (Nieuwhof and Michels 1983, Jaarsma 1991).

The traditional approach to these problems of rural opening-up is a planning for MRRs, based on economical and social considerations (OECD 1986). To guarantee accessibility for the growing multiple use of rural areas, an integral approach of minor and major roads is needed (Hawkins and Hat 1988). Kirchhoff, Hessel and Häcker (1996) advocate that this also holds for rural outdoor recreational activities, such as walking, jogging, cycling and driving for pleasure. In this paper we elaborate the idea that basically the unsafety problems (Jaarsma, 1994) and the environmental problems should be solved at a regional scale (van Langevelde and Jaarsma 1997). Such an integral approach includes weighting of accessibility benefits against traffic disbenefits. As an idea for such an integral planning in the Netherlands the spatial concept of the Traffic Calmed Rural Area (TCRA) is developed (Jaarsma and van Langevelde 1996).

The objective of this paper is to investigate the balance in right-of-way planning between accessibility and habitat fragmentation. The question will be addressed to what extent a planning approach based on the spatial concept TCRA facilitates rural opening-up, protecting the environment and a sustainable development.

## TRAFFIC ON MRRs AND ENVIRONMENTAL PROBLEMS

Most countries show a considerable growth of traffic volumes. In The Netherlands, average volumes outside built-up areas doubled between 1970 and 1990. Recent data per road category from the Dutch Statistical Office even show the largest growth rate for MRRs. Probably, the growing congestion on motorways is an explanation for this phenomenon (Jaarsma and van Langevelde 1996). For the United Kingdom, Stokes (1991) foresees that "traffic levels will rise dramatically in the countryside" between 1988 and 2025. On many MRRs capacity limits already appear. This enlarges the safety problems, especially for pedestrians and cyclists. Further, a declining livability for residents (annoyance, emissions) and an increasing habitat fragmentation for the fauna are inseparable from growing motorized traffic flows (Jaarsma 1996).

Four adverse effects of roads on species can be considered (after van der Fluit, Cuperus and Canters 1990): (1) destruction or alteration of habitat due to construction works, (2) physical barriers created by roads (increased resistance for movements), (3) disturbance of habitat along the roads (noise, vibrations, car visibility, etc.), (4) barriers by traffic (collision chance during crossing). The first two effects are related to the road itself: the larger the road, the larger the effect. For comparisons between roads, the clearance (Oxley, Fenton and Carmody 1974) and/or the width of pavement appear suitable measures. Both other effects are directly related to traffic volumes. Although disturbance includes more stimuli (Van der Zande, ter Keurs and van der Weijden 1980), the zone of disturbance may be estimated by a noise contour line, for example the 35 or 50 dB contour. Noise emission by car traffic is a causing factor for loss of habitat quality, for example for birds (Reijnen and Foppen 1994). To approach the barrier effect by traffic for larger mammals, the number of individuals killed by traffic (the mortality effect) is proposed. For this purpose, van Eupen and van der Veen (1995) developed a model for the probability of successful road crossing for a species. This traversability model is based on the assumption that a road crossing of an animal is successful, if an 'acceptable' gap in the traffic flow appears at the start of the crossing. A crossing during a smaller gap results in a collision, since an animal and a vehicle are at the same place at the same moment. The probability of gaps with a certain duration in a traffic flow is commonly based on the assumption of a Poisson distributed process. This probability only depends on the volumes. Crossing time depends on body size and traversing speed of the species and on the pavement width of the road. Van Langevelde and Jaarsma (1997) discuss the application of this model. They prefer a usage of the model for estimating the relative change of the traversability due to mitigating measures. The formulae applied are summarized in the Appendix.

For the role of MRRs in habitat fragmentation, few quantitative data are available. For the period 1960–1983, Berendsen (1986) made a classification of traffic kills for the badger *(Meles meles)* based on type of road. He found 8% of collisions concern motorways, 22% other trunk roads, 16% cent major roads and 54% MRRs. Derckx (1995) classifies recent data (1990–1994) by level of management (national, provincial or municipal road). With municipal roads considered to be MRRs, these data show similar percentages for MRRs. They also show a growing number of traffic kills (Table 1). Despite fencing and tunneling of motorways, the mortality effect of national roads (motorways and roads with limited access) is increasing. Among barn-

**Table 1. Traffic kills for the badger (*Meles meles*) in the Netherlands by type of road (classification by management), 1990–1994**

| Road type | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| National roads[1] (%) | 12 | 12 | 17 | 17 | 16 |
| Provincial roads (%) | 38 | 35 | 32 | 28 | 34 |
| Municipal roads (MRRs) (%) | 50 | 53 | 51 | 55 | 50 |
| Total traffic kills | 214 | 274 | 277 | 315 | 296 |

1. Including both motorways and roads with limited access.
Data elaborated from Derckx (1995).

owls *(Tyto alba)*, about 23% of traffic kills take place on MRRs (van den Tempel 1993). Probably, the role of MRRs in habitat fragmentation is substantial. It is true, MRRs are relatively small, so that their presence acts less frequently as a physical barrier. Further, their zones of disturbance are smaller. But on the contrary, the mesh size of MRRs is small. Many MRRs show considerable diffuse flows, spread all over the rural area. Therefore, the zones of disturbance may cover even larger acreages than zones of major roads. Since noise levels are ruled by a logarithmic relationship with volumes, a concentration of traffic flows on a few roads will decrease the overall level in an area.

## TRAFFIC CALMED RURAL AREAS: A SPATIAL CONCEPT

"Traffic calming refers to the adaption of existing road layouts in order to reduce the speed of vehicles travelling through areas where they are likely to come into conflict with other road users" (Macpherson 1993). This approach focuses on speed reduction, for example by speed humps (Bulpitt 1995). However, traffic calming in built-up areas may be a much wider idea. This is developed in the Dutch concept 'woonerf' in the 1970s, followed by the German 'Verkehrsberuhiging' in the 1980s (Vermeulen 1994). The basic principle is an integration of traffic in residential areas. This integration takes place based on priority being given to the needs of people, rather than to the needs of traffic.

The concept of the TCRA transfers these wider ideas on traffic calming from built-up areas to the rural area. Beside the needs of people, the needs of nature are considered (Jaarsma and van Langevelde 1996). The underlying idea is a clear separation between space for living and staying (for inhabitants and recreationists, but also for local fauna) and space for traffic flows. Starting point should be the desired spatial function of the rural area, not the appearing traffic flows. Usually, the residence functions will be stressed, not the flow functions for through traffic. "So, within the region roads will mainly have an access function, with a belonging (modest) technical layout. The region is surrounded and accessible by rural highways, with a flow function" (Jaarsma 1996).

Based on these ideas, several regional plans are developed. The planning procedure starts with a problem definition. Next, the desired functions to the links of the network are assigned. With a traffic model volumes per link are forecasted. Based on these prognoses, effects on traffic performance and road safety are calculated. Further, impacts on livability (approached by noise level) and on the barrier effect (approached by the collision chance, see Appendix) are estimated.

This approach of the TCRA holds a fundamental change in rural transportation planning: from following actual traffic flows to regulation of it. It results in a reorganization of traffic flows (Jaarsma and van Langevelde 1996):

- diffuse volumes at the MRRs will be concentrated at a few trunk roads;
- traffic flows at MRRs are rural bound (origin and/or destination along a MRR);
- volumes and speeds within the region will decrease.

It is expected, that such a reorganisation will both counter traffic unsafety and promote residential livability and habitat de-fragmentation within the region.

## CASE STUDIES

### Introduction

In 1989, a preliminary exercise with a TCRA is published (Jaarsma and Michels 1989). It applies to the Binnenveld, a rural area suffering from rat run traffic. In 1995, two studies followed. In one case, the coastal zone of Zealand Flanders, heavy recreational flows conflict with nature conservation (Jaarsma and Baltjes 1995). The other case, Gerdyksterwei, is a MRR with a high technical standard, conflicting with the ecological network and nature conservation (van Eupen and van der Veen 1995). In these cases, the problem definition, de proposed interventions, the expected volumes and the effects of the interventions are presented.

### The Binnenveld region

The Binnenveld region is a grassland area, situated between four towns: Ede, Wageningen, Rhenen and Veenendaal (Fig. 1). These towns are connected by a tangential system of major roads. The national east-west motorway A12 connects Ede and Veenendaal. There are provincial major roads between Ede and Wageningen, Wageningen and Rhenen and Rhenen and Veenendaal. For agricultural opening-up, a dense network of MRRs is present within this framework of major roads. Since they supply a shorter connection, especially for diagonal trips, several MRRs are abused by rat run traffic. Percentages of through traffic are high (Fig. 1). Unfavorable safety figures and damage to road construction and verges result from the high volumes on these roads.

Here, the idea of traffic calming implies a closure of the MRRs for through traffic, by legal or physical measures (cf. CROW 1989). Jaarsma and Michels (1989) calculated the impacts of a deviation of rat run traffic from the MRRs. First, traffic flow changes resulting from the proposed measures are determined for the relevant road sections. From this, the effects upon traffic performance (+4%), travel time (+5%), road safety (slightly negative), safety on crossings (slightly positive), energy consumption (+4%) and traffic noise are quantified. It is assumed that the impacts on habitat fragmentation may be estimated by the acreage of zones alongside the roads where the noise level is above 35 dB. For most MRRs this zone decreases with

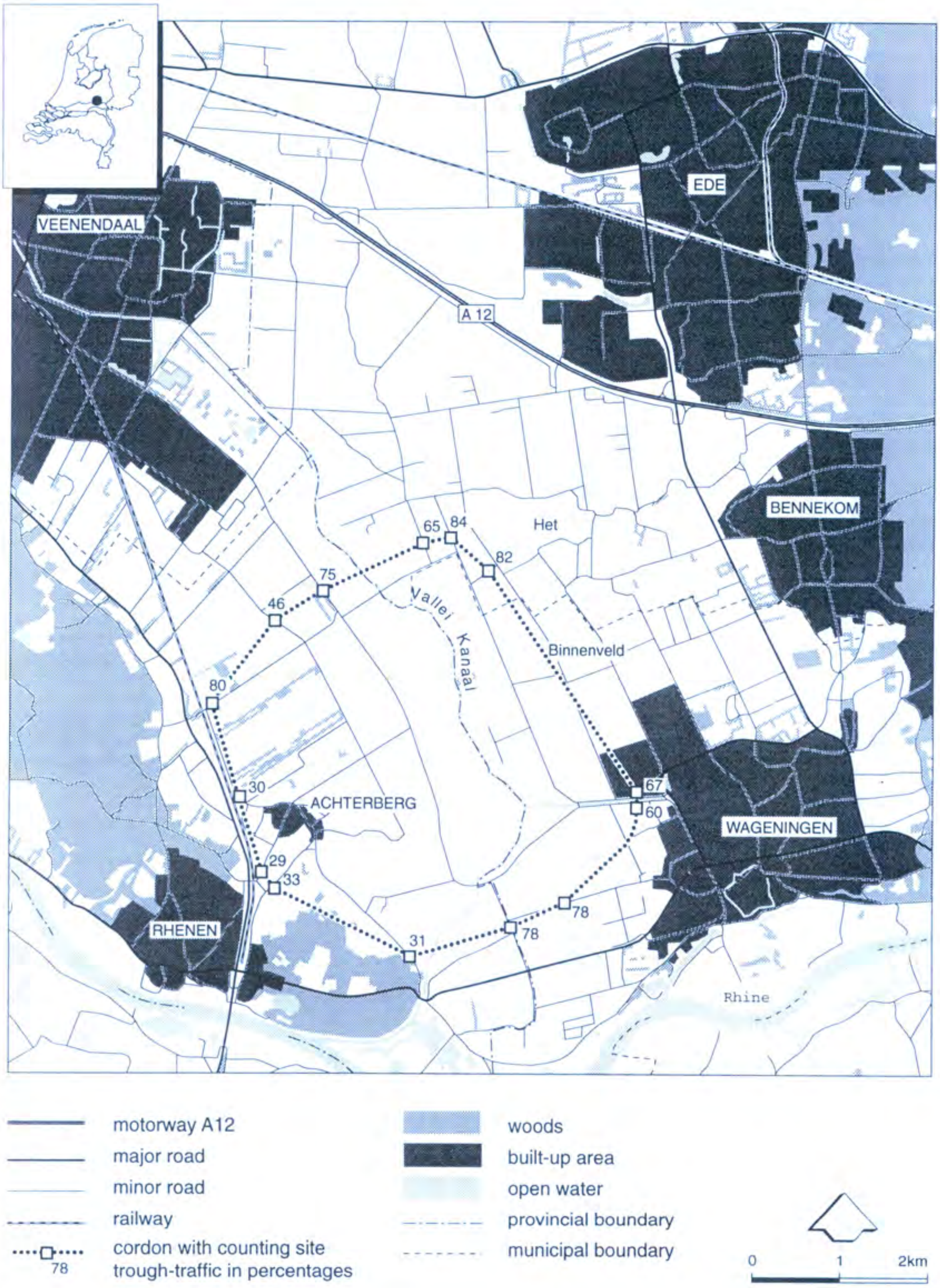



Fig. 1. The Binnenveld region.

100 to 200 m. The increase alongside major roads is smaller: only 50 to 100 m. As a result, the acreage with a level above 35 dB decreases with about 2%.

### Zealand Flanders

In the coastal region of the western part of Zealand Flanders (Fig. 2) conflicts arise between outdoor recreation, nature and agriculture. Motorized recreational traffic flows to the beaches decide the desired road layout. The main access road is a provincial road (N675), on a few kilometres parallel to the coast. It connects the villages with the national road (N58) to the ferry harbour near Breskens. However, flows are diffuse (Fig. 3). Especially, a considerable flow appears on the MRRs alongside the coastal dunes. This frustrates both recreational and nature development in the coastal zone.

As a solution to this problem, Fig. 2 suggests a lobate structure. It makes a distinction between more crowded and less crowded coastal zones. Here, traffic

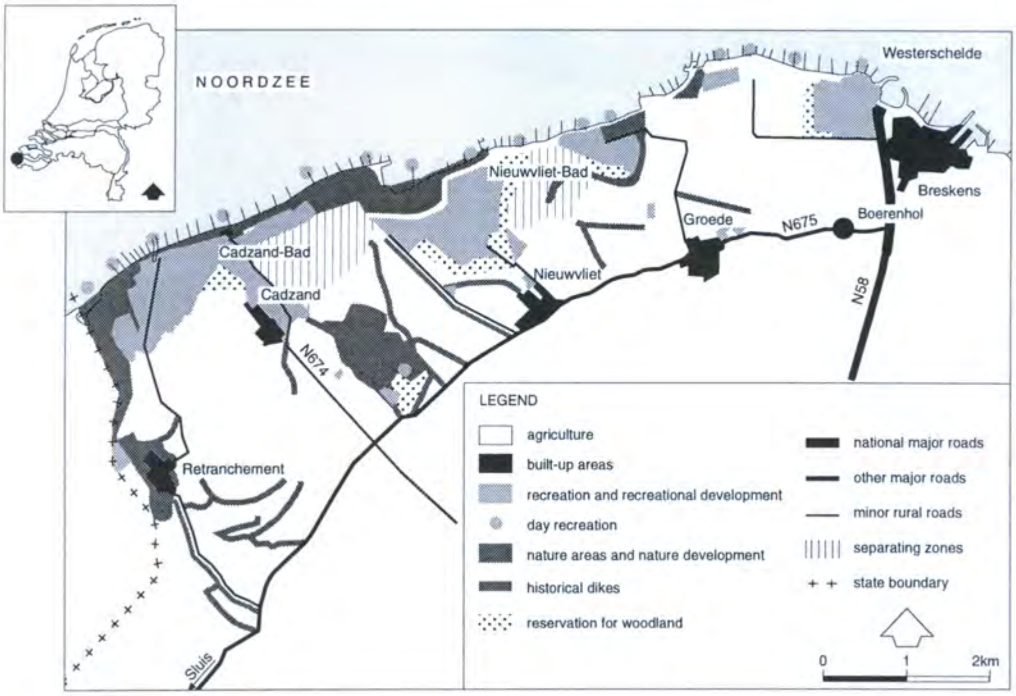



Fig. 2. Scheme of the lobate structure with opening up by "slagen", as indicated in the provincial physical plan (Jaarsma and Baltjes 1995).

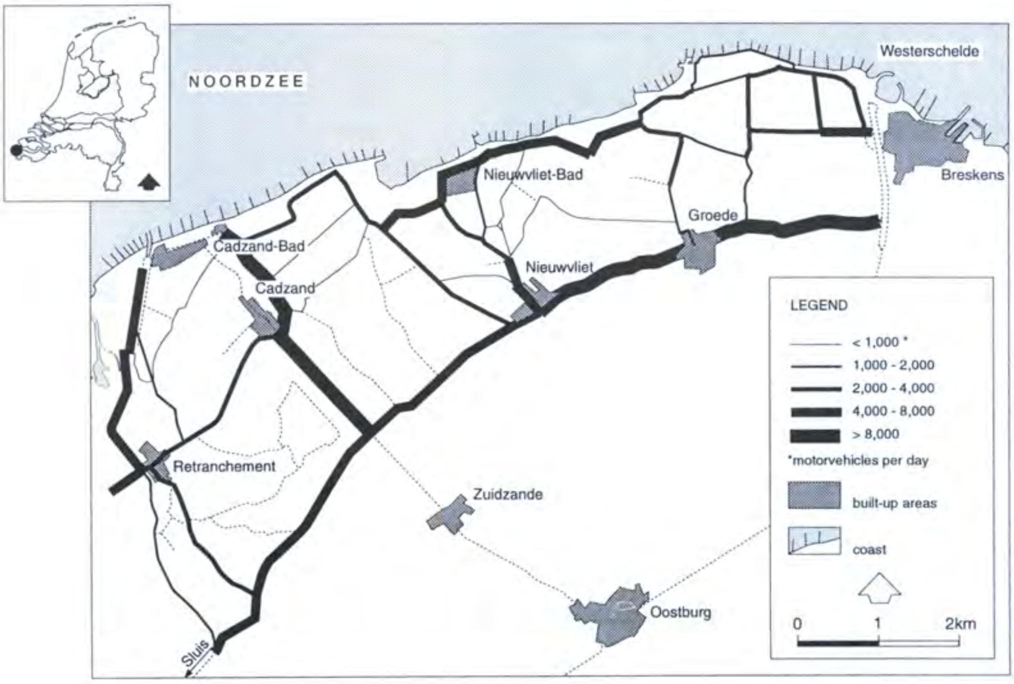



Fig. 3. Traffic volumes, as calculated for the autonomous development (Jaarsma and Baltjes 1995).

calming holds a low priority to the needs of traffic in the less crowded zones. The opening-up is coordinated with this principle by means of a so-called "slagen" structure, i.e., connections between the provincial major road (N675) and the beaches. These "slagen" are ending in a blind alley at the coast. They are situated in the crowded zones. Jaarsma and Baltjes (1995) investigate two to five alternative locations for each of the "slagen," connecting the four villages (Breskens/Groede, Nieuwvliet, Cadzand and Retranchement) with the coast. They calculate traffic volumes and their impacts for these alternative network solutions (Table 2). In comparison with the so-called autonomous development in Fig. 3, most of the alternatives produce more motorvehicle kilometres. However, by the concentration of traffic on the restricted number of "slagen", remaining

**Table 2. Effects for alternative locations (A...E) for the "slagen" connecting the four villages with the coast**

| "Slagen" to / effects on | Autonomous development | Alternative | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| Breskens/Groede | | | | | | |
| Performance[1] | 100 | 119 | 134 | 162 | 154 | |
| Safety[2] | 0.40 | 0.10 | 0.11 | 0.13 | 0.12 | |
| Accessibility[3,4] | | 4 | 3 | 1 | 2 | |
| Road capacity[5] | 14.5 | 0.8 | 0.8 | 2.9 | 3.1 | |
| Traffic noise[6] | | | | | no differences | |
| Nature development[3] | | 2 | 2 | 2 | 2 | |
| Nieuwvliet | | | | | | |
| Performance[1] | 100 | 95 | 78 | 80 | 82 | 84 |
| Safety[2] | 0.42 | 0.09 | 0.08 | 0.08 | 0.08 | 0.09 |
| Accessibility[3,4] | | 1 | 3 | 5 | 2 | 4 |
| Road capacity[5] | 13.5 | 4.6 | 1.5 | 0.9 | 3.0 | 0.9 |
| Traffic noise[6] | | –3 | +3 | +2 | –3 | –3 |
| Nature development[3] | | 1 | 5 | 3 | 5 | 3 |
| Cadzand | | | | | | |
| Performance[1] | 100 | 103 | 103 | | | |
| Safety[2] | 0.34 | 0.12 | 0.07 | | | |
| Accessibility[3,4] | | 2 | 4 | | | |
| Road capacity[5] | 9.3 | 5.0 | 1.4 | | | |
| Traffic noise[6] | | –1 | +1 | | | |
| Nature development[3] | | 4 | 4 | | | |
| Retranchement | | | | | | |
| Performance[1] | 100 | 100 | 100 | 137 | 142 | |
| Safety[2] | 0.35 | 0.09 | 0.09 | 0.10 | 0.10 | |
| Accessibility[3,4] | | 4 | 2 | 4 | 2 | |
| Road capacity[5] | 10.8 | 5.3 | 6.1 | 3.1 | 3.1 | |
| Traffic noise[6] | | –3 | +2 | –6 | +3 | |
| Nature development[3] | | 1 | 2 | 3 | 4 | |

1. In percentages; autonomous development = 100.
2. Number of traffic kills (based on accident rates per type of road).
3. Relative, 1 = worst and 4 (or 5) = best solution.
4. Travel time to the beaches and to the major camping sites.
5. Road length (kilometers) where calculated traffic volumes exceed road capacity.
6. Difference in noise level (dB(A)) for selected road links.
Data elaborated from Jaarsma and Baltjes (1995).

MRRs will have only modest volumes. This favors the opportunities for alternative modes, for example recreational biking.

With a "slagen" structure, traffic performance within the lobates decreases. Traffic flows on the provincial road (N675) increase. Differences between the alternatives are considerable. An overall reduction of traffic performance of 6% is possible. However, several alternatives include an increase of performance, up to 60%! Travel times along MRRs increase, because of a lower speed limit and the closure of the direct connection along the coast (Jaarsma and Baltjes 1995).

The impacts on habitat fragmentation are not defined directly in the study. Both, traffic noise and traversability are calculated for residential built-up areas only. Alternatives with low traffic volumes on MRRs near areas reserved for nature and/or nature development are considered to be favorable. Especially for the Nieuwvliet and Retranchement beaches, large differences between the alternatives appear for this aspect.

### Gerdyksterwei

The Gerdyksterwei is a former national road, between the Frisian villages Gorredijk and Beetsterzwaag (Fig. 4). Since it is bypassed by the A7 motorway, the Gerdyksterwei is a MRR. However, much traffic between Gorredijk and the nearby town of Drachten prefers this route above the functional route along the A7. Therefore, daily motorvehicle volumes on the Gerdyksterwei (4,100) and in the village of Beetsterzwaag (5,300) are high, where the motorway carries only 30,000 motorvehicles. The Gerdyksterwei intersects an

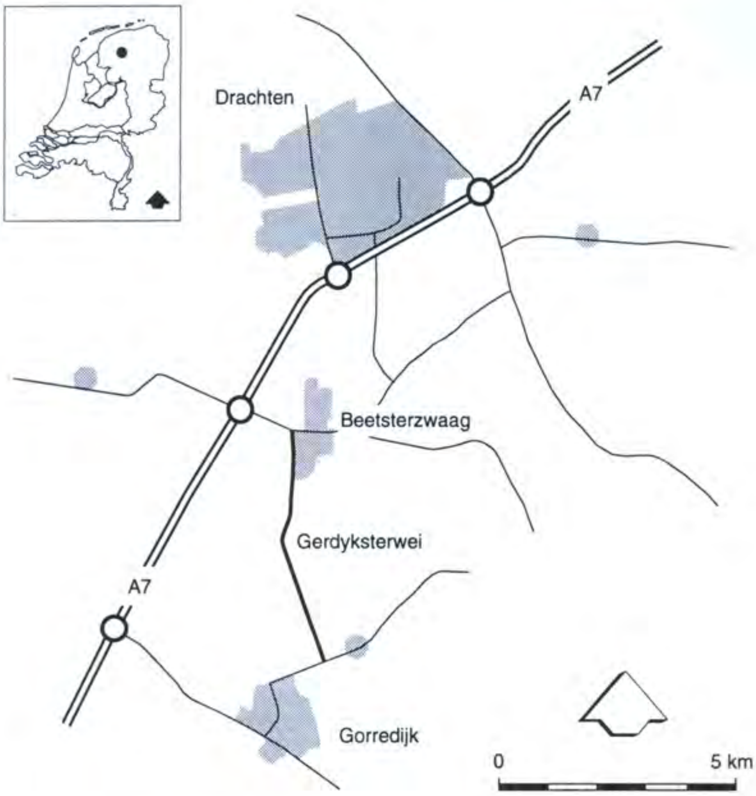



Fig. 4. The Gerdyksterwei in its regional context.

extended wooded area, which is a core area in the Dutch national ecological network. By its high volumes, the collision chance for crossing the Gerdyksterwei is considerable for species such as the roe deer (*Capreolus capreolus*), the pine marten (*Martes martes*) and (when re-introduced) the otter (*Lutra lutra*). Here, traffic calming means priority being given to nature, not to through traffic.

Van Eupen and van der Veen (1995) compare the collision chance for the present situation with the autonomous development (+ 1,000 vehicles in 2005) and a planned development, TCRA, without through traffic (–2,400 vehicles). In the latter situation, the lower volumes allow a reduced road capacity. So, pavement width may be reduced from 7 m now to 4 or 5 m. Using the formulae for successful road crossing (van Eupen and van der Veen 1995), as summarized in the Appendix, the impacts for the traversability (van Langevelde and Jaarsma 1997) for the Gerdyksterwei are calculated. Table 3 shows the resulting changes in traversability for the roe deer and the otter. (Results for the pine marten are not mentioned in the Table; these are close to those for the roe deer). For both species, most traffic victims fall during the night. Nightly volumes are estimated by the assumption of a quarter of the daily flow appearing between 7 p.m. and 7 a.m.

If traffic calming on the Gerdyksterwei is realized by an effective speed reduction, the travel time between Gorredijk and Beetsterzwaag will increase with approximately 45%. However, with a local closure, that forces local traffic along the A7, this will be 70%. For the through relationships Gorredijk-Drachten, differences are much smaller. Using the motorway A7 takes about 4% more time, despite the length of this route is about 20% longer (van Eupen and van der Veen 1995). Since the A7 is located in an open landscape, an increasing noise level is a disadvantage. However, this increase is only 0.3 dB.

## CONCLUSIONS AND DISCUSSION

To provide for peoples needs in the (near) future, the rural road network needs further improvements. Simultaneously, harmful effects of this network and its traffic flows affect local people, flora and fauna. Growing traffic volumes increase these problems. So, there is a need for a new planning approach, serving interests of both accessibility and a sustainable environment.

The spatial concept Traffic Calmed Rural Area (TCRA) is developed as a solution to this dilemma. In this concept, diffuse flows are concentrated as much as possible on a few roads, designed to cope with it. This marks two transitions. First, to a road planning in a wider perspective, and, second, from planning for road links to planning for road networks (Jaarsma 1996).

From three case studies, it is concluded:

- The TCRA will increase traffic performance and travel times. However, for most relationships the differences are small: in a range of a few minutes.

**Table 3. Traffic and ecological effects for roe deer (*r*) and otter (*o*) for the Gerdyksterwei: actual situation, autonomous development and four variations in traffic calming**

| | Actual situation | Autonomous development | Traffic calmed variations | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| Pavement width (m) | 7 | 7 | 7 | 6 | 5 | 4 |
| Volume[5] (veh $s^{-1}$) | $2.44\times10^{-2}$ | $3.00\times10^{-2}$ | $1.00\times10^{-2}$ | $1.00\times10^{-2}$ | $1.00\times10^{-2}$ | $1.00\times10^{-2}$ |
| $P_r$[6] | 0.981 | 0.976 | 0.992 | 0.993 | 0.994 | 0.995 |
| $P_o$[6] | 0.983 | 0.979 | 0.993 | 0.994 | 0.995 | 0.995 |
| $\Delta T_{t,r}$[7] | | –24 | +66 | +70 | +74 | +78 |
| $\Delta T_{t,o}$[7] | | –24 | +66 | +71 | +75 | +79 |

1. Without reduction of pavement width.
2–4. With reduced pavement width.
5. During the night.
6. $P_r$ is the probability of successful road crossing for the roe deer, and $P_o$ for the otter. The calculation is based on the assumptions (Van Eupen and Van der Veen 1995): $L_r = 1.4$ m and $V_r = 5.2$ m $s^{-1}$; $L_o = 1.2$ m and $V_o = 5.6$ m $s^{-1}$.
7. $\Delta T_t$ of the autonomous development is the predicted change (%) in mortality effect related to the actual situation, calculated for the roe deer and otter. A negative change implies an increase of traffic victims.
$\Delta T_t$ of the planned traffic calmed variations is the predicted change (%) in mortality effect related to the autonomous development.

- The TCRA gives a slight increase of the zones of disturbance along major roads (50–100 m at maximum). In the face of this, along a much longer length of MRRs this zone decreases with 100 to 200 m.
- Measured by the collision chance, the TCRA considerably improves the traversability of MRRs for larger mammals.

So, a regional planning approach for the rural road network according to the principles of the TCRA, is emphasized. It facilitates the management of rights-of-way, serving both rural accessibility and the environment. To realize this approach, several legal and physical measures are available (CROW 1989). However, commitment on the local level is important. This may be complicated, since local inhabitants often have different and sometimes conflicting interests. It is the task and the responsibility of the planners to involve both local inhabitants and local provincial and municipal government to weigh one against another and to reach consensus on desired functions and belonging layout for the links in the road network.

## REFERENCES


Berendsen, G. 1986. De das (*Meles meles* L.) als verkeersslachtoffer. (The badger as a traffic victim). RIN, Arnhem, Netherlands. 80 pp. (in Dutch)

Bohemen, H.D. van 1995. Mitigation and compensation of habitat fragmentation caused by roads: strategy, objectives, and practical measures. Transportation Research Record, 1475: 133–137.

Bulpitt, M. 1995. Traffic calming — have we given everyone the hump, or is it just a load of chicanery? Highways & Transportation, December: 8–10.

Canters, K.J. and R. Cuperus. 1995. Fragmentation of bird and mammal habitats by roads and traffic in transport regions. In: Proceedings of the Congress on Habitat Fragmentation and Infrastructure, Maastricht/The Hague, Netherlands, 18–21 September 18-21.

CROW (Centre for Research and Contract Standardization in Civil and Traffic Engineering) 1989. Verkeersmaatregelen in het buitengebied (Traffic measures in rural areas.) Mededeling 21, Ede (Neth.). ISBN 9066280840. 47 pp. (In Dutch).

Derckx, H. 1995. Dassen op weg. (Badgers on their way.) Landschap, 12: 39–44. (in Dutch).

Eupen, M. van and E. van der Veen. 1995. Versnippering van ecologische infrastructuur in relatie tot verkeersafwikkeling in landelijke gebieden; een gebiedsgerichte benadering in de gemeente Opsterland (Fragmentation of ecological infrastructure and traffic flows in rural areas: A regional directed approach in the municipality of Opsterland). MS thesis. Agricultural University, Wageningen, Netherlands. 110 pp. (in Dutch)

Fluit, N. van der, R. Cuperus, and K.J. Canters 1990. Mitigerende en compenserende maatregelen aan het hoofdwegennet voor het bevorderen van natuurwaarden (Mitigating and compensating measures to the national road network for helping nature values). CML mededelingen 65 Centrum voor Milieukunde, Rijksuniversiteit, Leiden, Netherlands. 98 pp. (in Dutch)

Hawkins, M.R. and M.J. Hatt. 1988. Managing a rural road network. In: Proceedings CIGR/PIARC Workshop Minor Rural Roads, Wageningen, Netherlands, 28–30 October 1987. Pudoc, Wageningen, Netherlands. ISBN 9022009653, pp. 55–65.

Jaarsma, C.F. 1991. Categories of rural roads in The Netherlands: functions, traffic characteristics and impacts. Some problems and solutions. In: Proceedings XIXth World Road Congress, Marrakech, Morocco, 22–28 September 1991. PIARC-publication 19.52E, pp. 101-103.

Jaarsma, C.F. 1994. Rural low-traffic roads (LTRs): the challenge for improvement of traffic safety for all road users. In: Proceedings 27th ISATA, dedicated Conference on Road and

Vehicle Safety, Aachen, Germany, 31 October–4 November, pp. 177–183.

Jaarsma, C.F. 1996. New approaches for the planning of rural road networks, within the frame of sustainable land use planning. In: Proceedings 2nd Workshop on Sustainable Land Use Planning, Gödöllö, Hungary, 4–6 September. (in print)

Jaarsma, C.F. and C.R. Baltjes. 1995. Herinrichting Kust West Zeeuwsch-Vlaanderen: ontsluiting onder de loep. Eindrapport: varianten voor een ontsluitingsstructuur met verkeersprognose en effectbepaling. (Reconstruction of the coastal region West Zealand Flanders: accessibility scrutinized). Nota vakgroep Ruimtelijke Planvorming 59, Wageningen, Netherlands. 140 pp. (in Dutch).

Jaarsma, C.F. and F. van Langevelde. 1996. The motor vehicle and the environment: balancing between accessibility and habitat fragmentation. In: Proceedings 29th ISATA, dedicated Conference on the Motor Vehicle and the Environment, Florence, Italy, 3–6 June, pp. 299–306.

Jaarsma, C.F. and Th. Michels. 1989. Verkeersplanning in landelijke gebieden: methode voor het kwantificeren van verkeerskundige effecten, toegepast op het Binnenveld. (Traffic planning in rural areas). Rapport 23, Winand Staring Centre, Wageningen, Netherlands. ISSN 0924-3070. 32 pp. (In Dutch).

Kirchhoff, P., C. Hessel, and S. Häcker. 1996. Verkehrsentlastung von grösseren Erholungsgebieten — Untersuchung am Beispiel des Landkreises Miesbach. Verkehr und Technik, 3: 115–118. (in German).

Langevelde, F. van and C.F. Jaarsma. 1997. Habitat fragmentation and infrastructure: the role of minor rural roads and their traversability. In: Selected Proceedings of the Congress on Habitat Fragmentation and Infrastructure, Maastricht/The Hague, Netherlands. 18–21 September (in print).

Macpherson, G. 1993. Highway and Transportation Engineering and Planning. Longman, Harlow, UK. ISBN 582097983. 385 pp.

Nieuwenhof, H. and Th. Michels. 1983. Verkeersonveiligheid op plattelandswegen. (Traffic unsafety on minor rural roads.) Cultuurtechnisch Tijdschrift, 23(2): 69–80. (In Dutch).

OECD (Organisation for Economic Co-operation and Development) 1986. Economic design of low-traffic roads. Paris (France), 116 pp.

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.

Reijnen, M.J.S.M. and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (*Phylloscopus trochilus*) breeding close to a highway. Journal of Applied Ecology, 31: 85–94.

Stokes, G. 1991. The effects of current trends in transport on the countryside in Great Britain. TSU ref 679, Oxford, UK. 14 pp.

Tempel, R. van den 1993. Vogelslachtoffers in het wegverkeer (Birds as victims in road traffic). Rapport 11 Vogelbescherming, Zeist, Netherlands, 103 pp. (in Dutch)

Vermeulen, W. 1994. Permanent safety, the road, the vehicle, the pedestrian. In: Proceedings 27th ISATA, dedicated Conference on Road and Vehicle Safety, Aachen, Germany, 31 October–4 November. pp. 97–102.

Zande, A.N. van der, W.J. ter Keurs, and W.J. van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat — evidence of a long-distance effect. Biological Conservation, 18: 299–321.

## APPENDIX: FORMULATION OF TRAVERSABILITY

The formulae for successful road crossing of animals are discussed by van Langevelde and Jaarsma (1997). The composing parts are summarized here.

First, the time $C$ needed for a road crossing can be calculated from:

$$C = \frac{(B + L_i)}{V_i} \tag{1}$$

where $B$ is the pavement width of the road, $L_i$ is the body size of the species $i$ (measured from snout to tail tip) and $V_i$ is the traversing speed of the species $i$. If the road has two lanes, for both lanes $\frac{1}{2}C$ seconds are needed.

Next, the theoretical probability $P_i$ of successful two-lane road crossing for a species $i$ is viewed as the probability of a gap of $\frac{1}{2}C$ in the first lane, directly followed by an equal gap in the second lane. This probability only depends on the volumes; it can be formulated in a decreasing exponential function, written as

$$P_i = e^{(-\lambda \cdot \frac{1}{2}C)} \tag{2}$$

where $\lambda$ is the decisive traffic volume of the two lane road. The decisive volume refers to the volumes at the periods of the day or season which corresponds to the species' period of movement (foraging, dispersal, etc.).

Third, the results from equation (2) are used to estimate the relative change of the traversability $\Delta T_i$ due to mitigating measures, written as

$$\Delta T_i = \frac{P_{i,2} - P_{i,1}}{P_{i,\text{opt}} - P_{i,1}} \times 100 \tag{3}$$

where parameter $P_{i,1}$ is the chance of successful road crossing in the actual situation, and $P_{i,2}$ for the planned development with width $B_2$ and traffic volume $\lambda_2$. The relative change of the traversability $\Delta T_i$ is calculated with regard to the optimum situation ($P_{i,\text{opt}} = 1$). A decrease of $\lambda$ and/or $B$ will result in an increase of $P_i$, and, therefore, in an increase of $\Delta T_i$. Due to the species-specific $V_i$ and $L_i$, the effects of changing $B$ and $\lambda$, and $\Delta T_i$ differ between species.

---

## *BIOGRAPHICAL SKETCHES*

***Catharinus Freerk (Rinus) Jaarsma***

*Department of Physical Planning and Rural Development, Wageningen Agricultural University, Generaal Foulkesweg 13, 6703 BJ Wageningen, The Netherlands*

Catharinus Freerk (Rinus) Jaarsma is a senior lecturer at the Wageningen Agricultural University, department of Physical Planning and Rural Development. He investigates rural road and traffic planning for several types of land use. Recently, the growing attention for environmental aspects as well as limited financial sources have given a new impulse to traffic research, within the wider perspective of environmental circumstances.

***Frank van Langevelde***

*Department of Physical Planning and Rural Development, Wageningen Agricultural University, Generaal Foulkesweg 13, 6703 BJ Wageningen, The Netherlands*

Frank van Langevelde is a Ph.D. student at the Wageningen Agricultural University, department of Physical Planning and Rural Development. His research focuses on fragmentation effects of forest birds, and the way these can be compensated and mitigated by planning ecological networks. Therefore, habitat selection and the role of connectivity in fragmented populations are investigated. Besides, research is carried out to habitat fragmentation and minor rural roads, and the way spatial planning provides defragmentation solutions based on the concept 'Traffic Calmed Rural Areas'.

# Effects of the Transmission System on Biodiversity in Sweden

**Lasse Kyläkorpi and Sture Gärdenäs**

Since the end of the 19th century, the total area of managed grassland (meadows and pastures) in Sweden has decreased from two million to less than 0.5 million ha. This change of land use has been recognized as a major threat to biodiversity, accounting for some 1000 species being placed on the official red list. During the same period, some 450,000 km of power line rights-of-way (ROW) has been created, covering a total area of about 0.3 million ha of open land. To secure biodiversity and cultural amenities, the Swedish government will spend the equivalent of 65 million US$ per year for the maintenance of about 370,000 ha of managed grassland. However, ROWs can provide complementary habitats for species hampered by the loss of managed grasslands. During 1996, Vattenfall, together with Svenska Kraftnät and Göteborg Energi, performed a life-cycle-assessment (LCA) on the distribution system of electricity. This paper focuses on the effects on the physical environment and biodiversity found in the study. The results indicate that ROW in Sweden have the capacity to influence biodiversity in a positive way. The maintenance of these relatively vast areas appear to favour those species normally dependent of traditional grassland management. Several of those species hampered by loss of grasslands have been found in ROWs in Sweden. There are also negative impacts, mainly related to bird collisions and pole materials, but these appear to be less significant than the positive effects.

*Keywords*: Transmission line, rights-of-way, ROW, Life-cycle-assessment, biodiversity, endangered species, grassland, dispersal corridors

## INTRODUCTION

### The structural change of the Swedish agricultural landscape

The agricultural era in Sweden began some 6,000 years ago. Habitats created as a result of fodder-production became significant 2,500 years ago, mainly because more manure from the livestock was needed to increase the crop production. This agricultural land use created a landscape, characterized by small-scale farming with numerous grassland plots interspersed with coppices of forest and wetland patches, forming a mosaic of different habitat types within small distance. These grazed or mown grasslands dominated the agricultural landscape in Sweden until the 1950s (Lennartsson and Svensson 1995).

Since the end of the 19th century, much of this land use has changed, mainly as a result of modern agricultural practices. Small farms have been amalgamated, cultivation hindrances have been removed and not the least, fertilizers have complemented manure. As a consequence, less land is needed for both grain production and cattle feeding. Thereby, the total area of managed grassland (meadows and pastures) in Sweden has decreased from two million to less than 0.5 million ha today (SCB 1996).

Of the remaining grasslands, less than 350,000 ha are unfertilized and regularly managed. Fewer than 4,000 ha of the most valuable hay producing (mown) grasslands are still in use (SCB 1996). These grasslands are considered one of the most diverse habitats in Sweden, with up to 40–50 different vascular plant species per square meter (Eknert 1995). The decrease of managed grasslands has been recognized as one of the major threats to biodiversity in Sweden, accounting for some 1,000 species being placed on the national list of threatened species (the red list) (Naturvårdsverket 1994). Altogether, more than 1,500 species in the agricultural landscape of Sweden are now found registered on the red list (Table 1) (Eknert 1995).

**Table 1. Threatened species by threat category in the agricultural landscape in Sweden (0 = Extinct, 1 = Endangered, 2 = Vulnerable, 3 = Rare and 4 = Care demanding) (compiled from Eknert 1995)**

| Type of organism | Threat category | | | | | Total no. of species |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | |
| Vertebrates | 6 | 7 | 13 | 2 | 27 | 55 |
| Invertebrates | 63 | 88 | 259 | 101 | 357 | 868 |
| Vascular plants | 24 | 70 | 80 | 58 | 73 | 305 |
| Bryophytes | 9 | 4 | 9 | 25 | 7 | 54 |
| Macrofungi | 2 | 33 | 37 | 37 | 64 | 173 |
| Lichens | 5 | 22 | 32 | 4 | 21 | 84 |
| Total | 109 | 224 | 430 | 227 | 549 | 1539 |

To preserve both natural and cultural amenities, the Swedish government, partly financed by environmental subsidies from the European Union (EU), will spend the equivalent of about 65 million US$ per year on maintenance of 370,000 ha of meadows and pastures (SCB 1996).

The Swedish power industry has also contributed to the changing of the landscape. Perhaps the most obvious influence is caused by ROWs. Such corridors require a total length of 450,000 km, covering an area of 300,000 ha (SNV 1993a), that has to be managed and kept free from high-growing vegetation.

### Life cycle assessment (LCA)

The power industry in Sweden, as well as other societal sectors, has realized the need of evaluating, analyzing and improving the environmental performance within all activities of their field. One of the most comprehensive methods of evaluating its specific impact, is by using life cycle assessment (LCA). Correctly performed, LCA provides a thorough and accurate tool by which a product's or service's environmental load, energy and resource use, during its full life cycle can be mapped and evaluated.

During 1996, Vattenfall — Sweden's largest producer and distributor of electricity — performed an LCA on the distribution system of electricity. The study, which was a cooperation with Svenska Kraftnät and Göteborg Energi, two major companies responsible for the transmission and purchase of electricity, embraced only the inventory and classification parts.

In this paper we discuss the effects on biodiversity found in the LCA study, and we also suggest methods to minimize the disadvantages and to maximize the positive effects of ROWs on biodiversity.

## METHODS

The LCA followed the guidelines of SETAC (Society of Environmental Toxicology and Chemistry) (Lindfors et al. 1995). According to the guidelines, one out of 13 effect categories in the classification procedure is biodiversity. Since the aim of the LCA was to map the total environmental load of the distribution system, the effect on biodiversity was considered important to describe.

There is as yet no consistent definition or generally accepted method of quantifying biodiversity, and even less to quantify effects on biodiversity (e.g., Monni and Lankinen 1995). On the basis of available data from studies undertaken in Sweden, we tried to make qualitative evaluations of both positive and negative effects on biodiversity that are likely to occur on transmission line ROWs.

A land use analysis of five stretches of ROW in Uppland (a region north of Stockholm) (60°N 18°E) was performed (Gärdenäs et al. 1996). The study embraced the electricity pathway from the main 400 kV-grid, via 220, 70 and 20 kV to the 10 kV local grid. The studied cables are overhead, except for the 10 kV-transmission which is an underground cable.

## RESULTS

### ROW land use

The land use analysis shows that 86% of the area occupied by the transmission line is located in the forest (Table 2). Even though forest is the dominant category, the forest pathway of the transmission line alters with passages through open areas. This means that there is a potential connection between the different open land categories, i.e., field, pasture and bog. This is important when discussing the proposed potential of ROWs as dispersal corridors. Over the total distance of 138 km, the power line crosses 48 open areas, giving an average distance between open areas along the pathway of 2.9 km.

### Biodiversity and electricity transmission; threats

*Bird collisions*

The transmission system, or more specifically power lines and transformers, can have negative effects on biodiversity, especially on various bird species. According to ArtDatabanken, the institution in charge of the Swedish official redlist, four bird species are endangered partly due to collisions with transmission lines and/or contact with transformers (Ahlén and Tjernberg 1996) (Table 3). However, there are relatively simple aids to reduce bird collisions with power lines. Tests with wire markers have been shown to decrease bird mortality (e.g. Alonso et al. 1994, Brown and Drewien 1995).

*Habitat fragmentation*

Open areas cutting through forests can cause negative effects on biodiversity by reducing dispersal of forest species, and thus causing fragmentation of valuable forest habitats and reducing population sizes. Such regional effects can also be induced by the establishment of ROWs (Monni and Lankinen 1995).

**Table 2. Results of the land use analysis of the five ROW stretches**

| | 400 kV | 220 kV | 70 kV | 20 kV | 10 kV* | Total | Share (%) |
|---|---|---|---|---|---|---|---|
| Length (km) | 51.6 | 31.4 | 47.0 | 7.6 | 4.5 | 140.1 | ~ |
| Width (m) | 46 | 40 | 30 | 10 | ~ | ~ | ~ |
| Forest (ha) | 223.1 | 110 | 103.5 | 5 | ~ | 441.6 | 86.3 |
| Field (ha) | 9.2 | 8.8 | 22.5 | 2.4 | ~ | 42.9 | 8.4 |
| Pasture (ha) | 0 | 0.8 | 8.4 | 0 | ~ | 9.2 | 1.8 |
| Bog (ha) | 1.8 | 0.8 | 0 | 0 | ~ | 2.6 | 0.5 |
| Imp. (ha) | 3.2 | 5.2 | 6.6 | 0.2 | ~ | 15.2 | 3.0 |
| No. of poles | 160 | 255 | 286 | 108 | ~ | 809 | ~ |
| Average distance (m) between poles | 322 | 123 | 164 | 70 | ~ | 170 | ~ |
| No. of open areas on the stretch | 8 | 9 | 23 | 8 | ~ | 48 | ~ |
| Average distance (km) between open areas | 5.8 | 1.8 | 1.4 | 0.6 | ~ | 2.9 | ~ |

*The 10 kV-line is an underground cable.
~Not applicable.

**Table 3. Threat category, degree of threat and number of additional threats for those four bird species put on the official red list, partly due to mortality from collision with transmission lines and/or contact with transformer units (compiled from Ahlén and Tjernberg 1996)**

| Species | Threat category | Degree of threat* | No. of additional threats |
|---|---|---|---|
| *Otis tarda* (Great bustard) | Extinct | 1 | 2 |
| *Ciconia ciconia* (White stork) | Extinct | 2 | 6 |
| *Bubo bubo* (Eagle owl) | Vulnerable | 2 | 6 |
| *Strix nebulosa* (Great grey owl) | Care demanding | 2 | 6 |

*1 = Important ongoing threat; 2 = less important ongoing or potential future threat.

### *Pole materials*

#### *Creosote*

Creosote has been used to prevent rotting of wood in Sweden since the beginning of this century. The poles in the Swedish distribution system contain an average of 135 kg creosote/$m^3$ wood (Bergqvist and Holmroos 1994). An average pole has a volume of 0.3 $m^3$ and thus contains approximately 45 kg of creosote. Studies has indicated that the creosote does not spread far from the poles in the ground (Bergqvist and Holmroos 1994). The volume of contaminated soil has been estimated at approximately 0.1 $m^3$ per pole.

#### *Arsenic*

The most common salt impregnation substance is CCA, type K-33 (Bard and Tapper 1989), which is a mixture of copper, chrome and arsenic salts. Theoretical calculations indicate that at most 15% of the arsenic in the pole can leak out, which means that some 0.5 $m^3$ of soil per pole may become contaminated.

Soil-living organisms are negatively affected by arsenic-pollution in the soil (Bard and Tapper 1989). At arsenic levels exceeding 150 mg/kg soil, the amount of bacteria, fungi and worms decrease (Bard and Tapper 1989). Such high levels have been measured up to 20 cm from the poles (Bergman 1991).

#### *Cadmium*

Zinc is used to prevent corrosion on poles, and it contains cadmium, which is very toxic for aquatic organisms and warm-blooded animals (SNV 1993b). The compound is characterized by its high degree of mobility and bioaccumulative capability in the natural environment. Because of this, toxic levels can occur in top predators of the ecosystems. Levels of cadmium in the ROW soils can increase by approximately 10% because of the impregnation of poles.

In arable land it is considered important to restrain the cadmium supply, to keep it below the theoretical value of 0.5 g per hectare and year (SNV 1993b). For the transmission system this means that the zinc used in poles in arable areas must be of the best possible quality (zinc is an antagonistic element to cadmium).

## Biodiversity and electricity transmission; possibilities

### *ROW management*

We used data from investigations conducted in other sites not far from the study area. For example, some 100 km west of the study site, outside the town of Fagersta, a botanically interesting site is situated in one 130-kV transmission line ROW (Nordin 1996). A number of grassland vascular plant species, some of them red-listed (e.g., *Botrychium virginianum, Gentianella campestris, Lathyrus heterophyllus*), are growing on this ROW. These are species that require some kind of management, such as grazing by cattle or hay harvesting (mowing) to persist. According to Ekstam and Forshed (1992), the latter two species generally disappear when management ceases. This indicates that the management of ROWs can favor those species that are dependent on the mowing and grazing of grasslands.

The species *Gentianella campestris* is undergoing a rapid decline. It has disappeared from 88–98% of the Swedish localities it was recorded 50 years ago (Lennartsson and Svensson 1995). The loss of grassland hectarage has been recognized as the main reason for this rapid deterioration.

In another ROW site, situated 100 km north-west of the study site, south-east of the city of Gävle, eastern Sweden, several redlisted butterfly species have been found. During 1993, more than three-quarters of the redlisted North-Swedish butterfly species were observed here (e.g., *Euphydryas aurinia, Melitaea diamina, Aricia donzels, Glaucopsyche alexis, Zygaena lonicerae, Z. viciae, Z. osterodensis*) (Swahn 1993). Beside this, a number of redlisted vascular plant species also are found here.

In 1993, Vattenfall received an award for the maintenance of this ROW. The award was given by the entomological society of Gästrikland (Swahn 1993).

*Dispersal corridors*

Preservation of biodiversity is a major concern of modern forestry. One popular approach in forest landscape planning is to protect ecologically valuable areas and linking them together with corridors of similar habitats, forming so called dispersal corridors (Gustafsson and Nohlgren 1995). Corridors promote dispersion of species between the protected areas to maintain genetic exchange between separated populations. The same line of argument could be applied when trying to preserve the biodiversity of the agricultural landscape of Sweden. There are valuable grassland areas spread throughout the landscape without any obvious connection between them, while a network of ROWs cut through these areas. It should be possible to plan and manage ROWs to promote species dispersion. Results from the land use analysis showed that the average distance between open areas along the studied ROW was less than three kilometers. This should increase the possibility for grassland species to disperse onto the ROWs.

*Edge zones*

ROWs increase the total length of zones separating two habitats (e.g. forest edges), known as ecotones. The highest diversity is found at the border between different ecosystems, e.g. between forests and clearcuts (Hansson 1983). It is likely that the borders between forests and open areas at ROWs can provide such habitats (Monni and Lankinen 1995). Hansson (1994) revealed a higher number of small mammal and bird species occurring in the forest edge compared to both that in the clear cut areas and in the internal forest. The ecotone function can be improved by creating softer edges with bushes, or, as proposed by Roseberry and Hill (1974), by cutting the edges in an irregular manner (in zigzag), thereby avoiding sharp and straight edges.

*Bird habitats*

Transmission systems also have positive effects on birds. Hansson (1983, 1994) found that different bird species preferred different parts of conifer forest clearcuts in Sweden. Some species (e.g., *Emberiza citrinella, Saxicola rubetra* and *Lanius collurio*), seemed to occupy the center parts of the open areas while other species (e.g., *Regulus regulus, Turdus merula, Phylloscopus trochilus, Fringilla coelebs, Turdus illiacus, Erithacus rubecula, Prunella modularis* and *Carduelis spinus*) preferred edges of surrounding forest. ROW clearcuts cause similar effects as do forestry strip felling areas (Monni and Lankinen 1995). This means that ROW management provides edge effects, which can be of benefit for some bird species.

*Mammal habitats*

Vegetation on ROWs has been found to attract large mammals. The elk (*Alces alces*) feeds on young deciduous trees (e.g., *Populus tremula, Sorbus aucuparia, Salix* sp.) that often grow in ROWs in Finland (Monni and Lankinen 1995). Hansson (1994) has found that elk preferentially occurred in the center of Mid-Swedish clearcuts.

## DISCUSSION

Based on available information as presented above, we conclude that ROWs have the capacity to influence biodiversity in a positive way. There are also negative impacts, mainly related to bird collisions and pole materials, but these appear to be less significant than the positive effects (Table 4). However, it should be possible to reduce the negative impacts by relatively simple means such as: (1) - choosing the proper pole (impregnation) material, (2) planning the ROW routes so that important habitats are not fragmented, and (3) using line markers and transformer screening devices in order to reduce bird mortality by collisions and electrocution.

**Table 4. Effects of ROW characteristics on biodiversity in Sweden. (++ means mainly positive impact, + means probable positive impact, 0 means no or insignificant impact, – means probable negative impact, and — means mainly negative impact. A question mark (?) means that the effects are unknown or uncertain.)**

| | Flora | Insects | Birds | Mammals | Soil organisms |
|---|---|---|---|---|---|
| Lines and transformers | 0 | 0 | – | 0 | 0 |
| Habitat fragmentation | – | – | 0 | – | ? |
| Pole material | – | 0 | ? | ? | – |
| ROW management | ++ | ++ | + | + | 0 |
| Edge zones | ? | ? | + | + | 0 |
| Dispersal corridors | + | + | 0 | + | 0 |

Also, the positive effects could be amplified by a number of measures, such as: (1) the adaptation of management strategies to local conditions, (2) improving the ecotone function by avoiding sharp/straight ROW edges, and (3) taking special precautions where redlisted species are present.

It also means that it should be possible to plan and manage future transmission line ROWs so that these positive effects are optimized from the beginning, and that negative effects can be reduced.

Our study indicates that ROW management in Sweden can be a resource in the preservation of those endangered species that are threatened by the altered land use due to modern agriculture. Four bird species have been placed on the red list because of conflicts with the transmission system. Several of those species that are endangered because of the decline in grassland hectarage, are promoted by the ROW management and can find a refuge on ROWs.

## ACKNOWLEDGMENTS

The authors wish to express their thanks to Magnus Blümer, Ulf Boman, Sven-Olov Ericson, Annemieke Gärdenäs, Eva Stattin and Björn Svensson for valuable comments on this paper.

## REFERENCES

Ahlén, I. and M. Tjernberg, eds. 1996. Rödlistade ryggradsdjur i Sverige — Artfakta. [Swedish Red Data Book of Vertebrates 1996]. ArtDatabanken, SLU, Uppsala, Sweden.

Alonso, J.C., J.A. Alonso, and R. Munoz-Pulido. 1994. Mitigation of bird collisions with transmission lines through groundwire marking. Biological Conservation, 67 (2): 129–134.

Bard, J. and M. Tapper. 1989. Undersökningar av kreosot-, koppar-, krom och arsenikföroreningar runt träimpregneringsverk på Gotland. Projektrapport från påbyggnadsutbildningen i ekotoxikologi. Zoofysiologiska institutionen Nr. 17. Uppsala universitet.

Bergman, Ö, 1991. Urlakning från tryckimpregnerat virke — En litteraturstudie [Leaching from pressure-treated wood — A literature survey] Svenska Träskyddsinstitutet Meddelanden Nr 163 [Swedish Wood Preservation Institute Reports No. 163].

Bergqvist, G. and S. Holmroos. 1994. Analys av kreosotstolpar i Simlångsdalen efter 40 års exponering i fält. [Analysis of creosote poles after 40 years of exposure] Vattenfall Utveckling AB Rapport Nr M205-252.92.

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 (2): 217–227.

Eknert, B. 1995. In: Mark, Människa, Miljö. Bydén, S., ed. pp. 53–73.

Ekstam, U. and N. Forshed. 1992. Om hävden upphör — Kärlväxter som indikatorarter i ängs- och hagmarker. [If grassland management ceases — Vascular plants as indicator species in meadows and pastures] Naturvårdsverket Förlag.

Gustafsson, L. and E. Nohlgren. 1995. Korridorer i den skogliga landskapsplaneringen [Dispersal corridors in forest landscape planning] SkogForsk Resultat Nr 8 1995.

Gärdenäs, S., B.-M. Brännström-Norberg, U. Dethlefsen, L. Kyläkorpi, R. Nordin, G. Malmqvist, C. Settervall and M. Tapper. 1996. Förstudie LCA Eldistribution. Rapport från Vattenfall Utveckling AB Rapportnr. UY 96:Ö5.

Hansson, L. 1983. Bird numbers across edges between mature conifer forest and clearcuts in central Sweden. Ornis Scandinavica, 14: 97–103.

Hansson, L. 1994. Edge effects in managed forests and implications for conservation. Metsäntutkimuslaitoksen tiedantoja, 482: 69–73.

Lennartsson, T. and R. Svensson. 1995. Patterns in the decline of three species of Gentianella (Gentianaceae) in Sweden illustrating the deterioration of semi-natural grasslands. Acta Univ. Ups. Symb. Bot. Ups. 31 (3): 169–184.

Lindfors, L.-G., K. Christiansen, Y. Virtanen and O.-J. Hanssen. 1995. Nordic Guidelines on Life-Cycle Assessment. Köpenhamn, Nordiska Ministerådet.

Monni, S. and A. Lankinen. 1995. Sähkön tuotannon ja siirron biodiversiteettivaikutusten arviointimahdollisuudet. [The possibilities to estimate the impacts of electricity production and transmission on biodiversity] Publications in Botany from the University of Helsinki No. 21, 158 pp.

Naturvårdsverket. 1994. Biologisk mångfald i Sverige: En landstudie. Monitor 14. Naturvårdverket Förlag [Swedish EPA].

Nordin, L.-T. 1996. Personal letter. Kalmar kommun, Sweden. 20 November.

Roseberry, J.T. and J.A. Hill. 1974. Power transmission lines: An overview of problems, values and potential for wildlife. Transactions of the Northeast Section of the Wildlife Society, 31: 7–14.

SCB. 1996. Naturmiljön i siffror. Femte utgåvan. [The Natural Environment in Figures] Statistiska centralbyrån. [Official Statistics of Sweden]

SNV. 1993a. Markanvändningen och miljön. SNV Rapport 41 37. Naturvårdsverket [Swedish EPA].

SNV. 1993b. Metallerna och miljön. SNV Rapport 41 35. Naturvårdsverket [Swedish EPA].

Swahn, U. 1993. När? Hur? Varför? Insectifera 1.2. Gävle, December 1993. pp. 20–21.

---

## *BIOGRAPHICAL SKETCHES*

***Lasse Kyläkorpi***

*Vattenfall Hydropower AB, P.O. Box 533, SE-162 16 Stockholm, Sweden*

Lasse Kyläkorpi, Environmental consultant. M.Sc. in Biology and Earth sciences, University of Stockholm. Mainly working with EIAs in different branches within the energy business, such as transmission and hydro power. Involved in a national research project concerning the effects of land use on biodiversity.

***Sture Gärdenäs***

*Vattenfall Utveckling AB, SE-162 87, Stockholm, Sweden*

Sture Gärdenäs, Senior research engineer. Chemistry engineer, Royal College of Technology, Stockholm. Coordinator of a cooperation between Vattenfall, LRF/the Federation of Swedish Farmers and the Swedish Forest-Owners Association. Project leader of the LCA on the distribution system of electricity.

# Evaluation of Different Grasses to Restore Wetlands and Control Weed Species after Pipeline Construction

**Joseph M. McMullen, Mark E. Burger, and Scott D. Shupe**

In the northeastern United States, two invasive weed species of vegetation, common reedgrass (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), invade and degrade wetlands. Soil disturbance during pipeline construction can promote the invasion of these aggressive weed species into wetland areas. To assess this concern, a three-year research project was implemented to assess the ability of three different restoration grasses — Japanese millet (*Echinochloa crusgalli*), annual ryegrass (*Lolium* spp.), and redtop (*Agrostis gigantea*) — and natural regeneration in their ability to stabilize disturbed wetland areas and restrict the invasion of weed species. Organic soil wetlands along a pipeline constructed in upstate New York in 1994 were studied. Grasses were planted in randomly selected plots in the summer of 1994. Vegetation data were collected along permanent transects in each plot in 1994, 1995 and 1996. Initial differences among grass treatments were noted, especially in the millet plots where total vegetation cover was high, but plant species richness was low. By the third year of study, dominant plant species composition was identical in all treatment plots, including untreated control. Loosestrife invaded the wetland areas and by the third year had somewhat similar values among all treatments. Common reedgrass never invaded the disturbed wetland areas. Results of the study question the need for and benefit of planting restoration grasses in wetlands where topsoil and grades are restored.

*Keywords*: Weed species, common reedgrass, purple loosestrife, pipeline construction, wetland restoration, Japanese millet, annual ryegrass, redtop, wetland vegetation, wetlands disturbance, organic soil, rights-of-way

## OBJECTIVE

The objective of this study was to evaluate the ability of three different grasses Japanese millet *Echinochloa crus-galli)*, annual ryegrass (*Lolium* spp.), and redtop (*Agrostis gigantea*) and natural regeneration in their ability to stabilize wetlands, and prevent the invasion of common reedgrass and purple loosestrife into wetland areas within rights-of-way disturbed by pipeline construction.

## INTRODUCTION

In the northeastern United States, two invasive weed species of vegetation, common reedgrass (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), have begun to invade wetlands. These species of vegetation are of little value to wildlife. They germinate and grow quickly and prevent native wetland vegetation, which provides necessary food and cover for wildlife, from becoming established. Soil disturbance during pipeline construction can promote the invasion of these aggressive weed species into wetland areas.

To assess the concern of weed species invasion, Niagara Mohawk Power Corporation began a research project during the summer of 1994 immediately after wetlands were disturbed by pipeline construction (TES 1996). The pipeline studied is referred to as Natural Gas Pipeline No. 63, and extends through Oswego County, New York (Fig. 1).

The pipeline crossed many areas of wetlands regulated by the New York State Department of Environmental Conservation (NYS DEC) and the U.S. Army


Fig. 1. General location of wetland areas used for the grass treatments along natural gas transmission pipeline no. 63, Oswego County, New York.

Corps of Engineers (COE). Conditions of the COE permit required that topsoil in the upper organic layer up to 40.6 cm (16 inches) of all wetlands be removed and stockpiled separately from subsoil during trenching operations. Upon completion of construction activities, topsoil was returned to the trench. Contours were required to be restored to several inches below original grade and/or seeded immediately with a suitable competitor species, such as annual ryegrass. All restoration work, including seeding and restoring of contours, was to be completed within 72 hours of backfilling.

The long-term success of seeding grasses to stabilize disturbed wetlands areas and restrict weed species has not been tested. The three different grasses selected for the seeding treatments were: Japanese millet, annual ryegrass, and redtop. These grasses were selected because of their availability and common use on restoration projects. Two different wetland study areas in organic (muck) soils were selected for the grass seeding treatments (Fig. 1). Each grass treatment area was monitored for three growing seasons after planting.

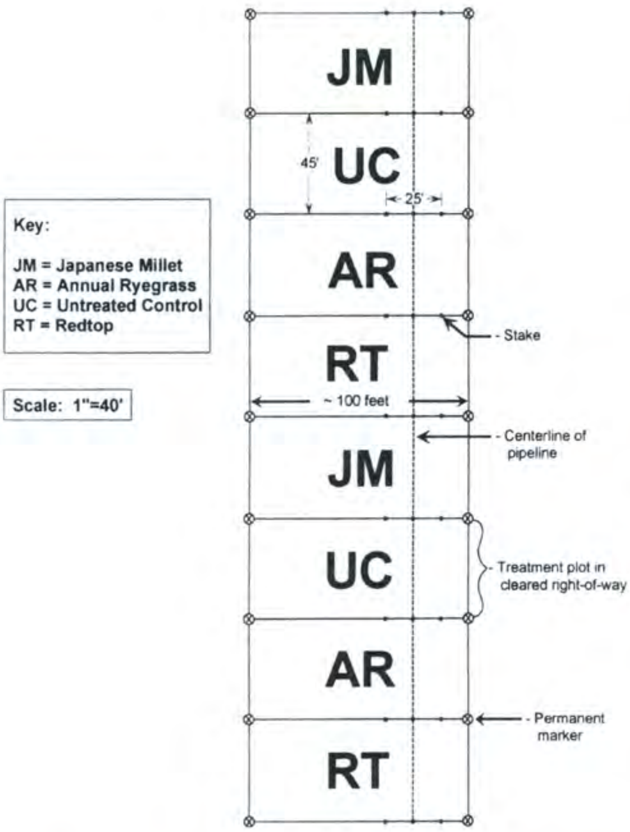



Fig. 2. Schematic of possible treatment plot arrangement within a treatment block.

## METHODS

### Grass treatment plot layout

The disturbed portion of the selected wetland study areas within the gas pipeline right-of-way were divided into plots for the purposes of the grass seeding. Each plot was the width of the disturbed portion of the right-of-way (approximately 30 m [100 ft]) and 13.6 m (45 ft) in length along the long axis of the right-of-way (Fig. 2).

Within each wetland study area, eight different treatment plots were delineated (Fig. 2). This series of eight plots was referred to as a block. With eight plots in each block, two replicates of each of the three grass treatments (Japanese millet, annual ryegrass, and red top) and untreated plot were permitted in each wetland study area. Replicates averaged out differences between soils and hydrology in each block.

Wood stakes were also used to delineate the boundary between pipeline trench area and remaining disturbed work areas within each plot. The trench area was approximately 6.1 m (20 ft) wide and existed where soil was excavated for placement of the pipe. Disturbed areas consisted of spoil areas where soil from the trench excavation was temporarily stored or other work areas where soil was disturbed.

### Grass seeding treatment application

After the plots were staked-out, they were seeded with the selected grass species. Seed application was selected at random for the first four plots, and this random order repeated in the second four plots of each treatment block (Fig. 2).

The application rate of the seed varied by the grass species. Seed was weighed in the field with a triple-beam balance scale and hand applied with a cyclone spreader. The rate of application of seed was as follows: Japanese millet — 24.4 kg/ha (21.8 lb/acre); annual ryegrass — 48.8 kg/ha (43.6 lb/acre); redtop — 34.3 kg/ha (30.6 lb/acre); and no treatment (untreated control). Dates of the actual seeding are shown in Table 1.

### Post-seeding sampling (1994, 1995, 1996)

Vegetation was sampled in September 1994, in June and again in September 1995, and in September 1996. In 1995, the two sampling periods, one in early summer and the other in early fall, were to assess seasonal differences in the plant community composition.

During all sampling periods, species composition and vegetation cover data were recorded using the line-intercept method. Line-intercept was performed by stretching a 10-m tape between two permanent stakes. Percent cover is recorded by plant species in each of the ten, one-meter intervals that comprise the 10-m transect line. Each plant or plant part that intercepts an imaginary plane above and below the 10-m line is recorded by species (Lindsey 1956, Kisslinger et al. 1960).

Two 10-m transects were sampled in each plot. One transect was centered over the trench area and one in the remaining disturbed work area of the pipeline right-of-way. End points of the transect were marked with permanent wooden stakes and the same transect sampled in each year. Direction of each transect was selected at random.

**Table 1. Grass seeding and sampling dates for grass treatment research project**

| Wetland study area | Plot layout | Initial soil and hydrology sampling | Grass seeding | Sept. 1994 vegetation sampling | June 1995 vegetation sampling | Sept. 1995 vegetation sampling | Sept. 1996 vegetation sampling |
|---|---|---|---|---|---|---|---|
| VCN-9 (north) | 30 June 1994 | 1 July 1994 | 1 & 5 July 1994 | 15 & 16 Sept. | 20 June | 12 Sept. | 6 Sept. |
| VCN-9 (south) | 30 June 1994 | 1 July 1994 | 1 & 5 July 1994 | 15 & 16 Sept. | 20 & 21 June | 12 & 15 Sept. | 6 & 10 Sept. |
| VCN-19 | 20 July 1994 | 20 July 1994 | 21 July 1994 | 16 & 19 Sept. | 21 June | 15 Sept. | 10 Sept. |

Vegetation data were analyzed using the methods described in Cox (1972). Using this methodology, actual and relative values are determined for frequency and dominance by each plant species. An importance value, which is a summary of the relative frequency and relative dominance, is also determined. Frequency is a measure of a plant's spatial distribution. Actual frequency is the percent of sampling intervals occupied by a given species. It is determined by dividing the number of 1-m intervals in which a species is recorded by the total number of 1-m intervals sampled. If a species occurs in five out of ten samples, it has an actual frequency of 50%. Dominance is determined by using cover data. Actual dominance is determined by dividing the cover recorded for a given species by the total amount of cover available in the intervals sampled. For example, a species that covers 50% of the area sampled would have an actual dominance of 50%. Relative frequency is the actual frequency of a given species divided by the actual frequency of all species in the sampling set. Relative dominance is the actual dominance of a given species divided by the total actual dominance of all species in the sampling set.

Total vegetation cover and species richness values were also determined. Total vegetation cover is a measure of the area occupied by vegetation (regardless of species) as opposed to bare ground. Species richness is the total number of species recorded.

## DESCRIPTION OF WETLAND STUDY AREAS

The wetland study areas occur in south-central Oswego County, New York. Wetlands in this portion of Oswego County owe their genesis to receding waters of glacial Lake Iroquois. During de-glaciation of the region about 10,000 years ago the wetlands formed in depressions in low areas where drainage was blocked by glacial deposits (Jones et al. 1983). Many of these wetlands consist of impermeable or slightly permeable drift deposits. Overtop these layers exist a relatively thick accumulation of organic matter. Other wetlands in this region are a result of lacustrine lake silt and clay deposits that were deposited within inter-drumlin lowlands. The poor drainage of these soils, and their position on the topography, have promoted the formation of many wetlands in this region of Oswego County, New York.

The wetland study areas were primarily young deciduous forest wetlands prior to the pipeline construction, although they are adjacent to a cleared right-of-way where an emergent wetland dominates. The forested wetland was dominated by: red maple (*Acer rubrum*) and green ash (*Fraxinus pennsylvanica*) trees; shrubs of alder (*Alnus rugosa*), spicebush (*Lindera benzoin*), and arrowwood (*Viburnum recognitum*); with cinnamon fern (*Osmunda cinnamomea*), manna grass (*Glyceria* sp.), and royal fern (*Osmunda regalis*) common herbaceous species. The emergent wetland in the adjacent cleared right-of-way was dominated by cattail (*Typha latifolia*), purple loosestrife, sensitive fern (*Onoclea sensibilis*), and sedges (*Carex* spp.).

Soils in these wetland study areas were a black, deep muck, classified as Palms and Carlisle muck (USSCS 1981). These mucks have a deep organic layer often overlying marl. Water in these wetlands is pooled during wet periods, with saturation near the surface for much of the year.

## RESULTS AND DISCUSSION

### Plant species composition

Dominant plant species are generally used to characterize the species composition of an area. The dominant species are roughly defined as those that cumulatively total more than 50% of importance value. Dominant plant species in the four treatment types in 1994, 1995 and 1996 are presented in Tables 2–5. Vegetation data include: actual and relative frequency, actual and relative cover, and importance value. Total vegetation cover values for the four treatment types over the three-year study are presented in Table 6, with species richness values in Table 7.

During initial vegetation establishment in these wetlands, rice cutgrass (*Leersia oryzoides*), swamp beggar ticks (*Bidens connata*), cattail, sedge, manna grass, water purslane (*Ludwigia palustris*), and purple loosestrife were prevalent (Tables 2–5). Except for cattail, none of these species were common prior to pipeline construction, but were abundant two years after restoration.

It is important to note that by the end of the third growing season (September 1996) in these organic soil wetlands, the dominant species present were the same in each wetland, regardless of treatment. These species of vegetation and the order of their dominance were: rice cutgrass, broad-leaf cattail (*Typha latifolia*), and purple loosestrife (Tables 2–5).

Results of the three-year study showed that Japanese millet (an annual) germinated the fastest, with plants visible within four days of planting. It was the tallest of the planted grasses, had the densest cover, and even grew in areas of pooled water. In effect, millet established a monoculture in the first year. Millet, when mature, produced a large seed head that provided food and cover for wildlife. During the first growing season Japanese millet grew superiorly under all conditions (Table 2). Although millet initially restricted the invasion of purple loosestrife and common reedgrass (Table 8), it also restricted the growth of other wetland vegetation as reflected by the lowest species richness of any of the treatments (Table 7). During the second growing season, millet did not reseed itself, leaving the soil relatively barren. By the fall 1995 sampling, natural wetland vegetation began to establish. During the third growing season, natural

**Table 2. Dominant plant species composition in Japanese millet plots, organic soil wetlands**

| | Frequency (%) | | Dominance | | Importance value |
|---|---|---|---|---|---|
| | Actual | Relative | Actual (% cover) | Relative (%) | |
| September 1994: | | | | | |
| *Echinochloa crusgalli* (Japanese millet) | 85.8 | 54.8 | 61.5 | 86.7 | 141.5 |
| June 1995: | | | | | |
| *Bidens connata* (Swamp beggar ticks) | 40.0 | 12.7 | 12.7 | 25.9 | 38.6 |
| *Echinochloa crusgalli* (Japanese millet) | 54.2 | 17.2 | 8.2 | 16.8 | 34.0 |
| *Glyceria striata* (Manna grass) | 21.7 | 6.9 | 5.3 | 10.9 | 17.8 |
| *Lythrum salicaria* (Purple loosestrife) | 31.7 | 10.1 | 2.6 | 5.2 | 15.3 |
| September 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 76.7 | 16.4 | 30.1 | 22.8 | 39.2 |
| *Bidens connata* (Swamp beggar ticks) | 65.8 | 14.1 | 30.2 | 22.9 | 37.0 |
| *Echinochloa crusgalli* (Japanese millet) | 39.2 | 8.4 | 10.3 | 7.8 | 16.2 |
| *Typha latifolia* (Broad-leaf cattail) | 37.5 | 8.0 | 9.9 | 7.5 | 15.6 |
| September 1996: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 92.5 | 19.4 | 45.8 | 34.0 | 53.4 |
| *Typha latifolia* (Broadleaf cattail) | 58.3 | 12.2 | 14.7 | 10.9 | 23.1 |
| *Lythrum salicaria* (Purple loosestrife) | 51.7 | 10.8 | 14.9 | 11.0 | 21.9 |
| *Ludwigia palustris* (Water purslane) | 31.7 | 6.6 | 14.4 | 10.7 | 17.3 |

**Table 3. Dominant plant species composition in annual ryegrass plots, organic soil wetlands**

| | Frequency (%) | | Dominance | | Importance value |
|---|---|---|---|---|---|
| | Actual | Relative | Actual (% cover) | Relative (%) | |
| September 1994: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 43.3 | 16.3 | 12.5 | 24.8 | 41.0 |
| *Bidens connata* (Swamp beggar ticks) | 32.5 | 12.2 | 8.3 | 16.3 | 28.5 |
| *Lolium* sp. (Annual ryegrass) | 37.5 | 14.1 | 6.2 | 12.2 | 26.3 |
| *Echinochloa crusgalli* (Japanese millet) | 25.0 | 9.4 | 7.8 | 15.5 | 24.9 |
| June 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 55.5 | 14.4 | 15.4 | 18.0 | 32.5 |
| *Typha latifolia* (Broadleaf cattail) | 48.2 | 12.5 | 11.4 | 13.3 | 25.9 |
| *Glyceria striata* (Manna grass) | 35.5 | 9.2 | 14.1 | 16.5 | 25.7 |
| *Bidens connata* (Swamp beggar ticks) | 29.1 | 7.6 | 8.2 | 9.6 | 17.2 |
| September 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 80.0 | 17.6 | 47.1 | 30.7 | 48.4 |
| *Typha latifolia* (Broadleaf cattail) | 79.2 | 17.4 | 25.3 | 16.5 | 34.0 |
| *Lythrum salicaria* (Purple loosestrife) | 49.2 | 10.8 | 11.3 | 7.3 | 18.2 |
| September 1996: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 85.0 | 18.1 | 36.8 | 26.2 | 44.4 |
| *Typha latifolia* (Broadleaf cattail) | 81.7 | 17.4 | 30.5 | 21.8 | 39.2 |
| *Lythrum salicaria* (Purple loosestrife) | 49.2 | 10.5 | 10.7 | 7.6 | 18.1 |

**Table 4. Dominant plant species composition in redtop plots, organic soil wetlands**

| | Frequency (%) | | Dominance | | Importance value |
|---|---|---|---|---|---|
| | Actual | Relative | Actual (% cover) | Relative (%) | |
| September 1994: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 58.3 | 16.7 | 18.8 | 26.4 | 43.1 |
| *Bidens connata* (Swamp beggar ticks) | 46.7 | 13.4 | 12.0 | 16.8 | 30.2 |
| *Ludwigia palustris* (Water purslane) | 45.0 | 12.9 | 12.0 | 16.9 | 29.8 |
| June 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 52.5 | 12.5 | 16.7 | 17.4 | 29.9 |
| *Agrostis gigantea* (Redtop) | 45.8 | 10.9 | 15.7 | 16.4 | 27.3 |
| *Typha latifolia* (Broad-leaf cattail) | 55.0 | 13.1 | 9.9 | 10.3 | 23.4 |
| *Carex stipata* (Sedge) | 47.5 | 11.3 | 9.1 | 9.5 | 20.8 |
| September 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 85.0 | 17.7 | 52.5 | 33.1 | 50.8 |
| *Typha latifolia* (Broad-leaf cattail) | 65.8 | 13.7 | 16.6 | 10.5 | 24.2 |
| *Carex* sp. (Sedge) | 61.7 | 12.8 | 15.7 | 9.9 | 22.8 |
| *Agrostis gigantea* (Redtop) | 38.3 | 8.0 | 14.2 | 9.0 | 16.9 |
| September 1996: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 90.0 | 18.2 | 44.0 | 29.5 | 47.7 |
| *Typha latifolia* (Broad-leaf cattail) | 73.3 | 14.8 | 23.6 | 15.8 | 30.7 |
| *Lythrum salicaria* (Purple loosestrife) | 50.8 | 10.3 | 11.5 | 7.7 | 18.0 |
| *Carex comosa* (Sedge) | 45.8 | 9.3 | 11.0 | 7.4 | 16.7 |

**Table 5. Dominant plant species composition in untreated control plots, organic soil wetlands**

| | Frequency (%) | | Dominance | | Importance value |
|---|---|---|---|---|---|
| | Actual | Relative | Actual (% cover) | Relative (%) | |
| September 1994: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 49.2 | 18.4 | 15.1 | 25.5 | 43.9 |
| *Bidens connata* (Swamp beggar ticks) | 44.2 | 16.5 | 12.0 | 20.3 | 36.8 |
| *Ludwigia palustris* (Water purslane) | 35.8 | 13.4 | 10.6 | 17.8 | 31.2 |
| June 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 47.5 | 12.9 | 12.4 | 14.7 | 27.6 |
| *Typha latifolia* (Broad-leaf cattail) | 47.5 | 12.9 | 11.1 | 13.1 | 26.0 |
| *Glyceria striata* (Manna grass) | 26.7 | 7.2 | 9.6 | 11.4 | 18.6 |
| *Ludwigia palustris* (Water purslane) | 31.7 | 8.6 | 8.5 | 10.0 | 18.6 |
| *Carex stipata* (Sedge) | 37.5 | 10.2 | 6.8 | 8.1 | 18.3 |
| September 1995: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 85.0 | 17.7 | 52.5 | 33.1 | 50.8 |
| *Typha latifolia* (Broad-leaf cattail) | 65.8 | 13.7 | 16.6 | 10.5 | 24.2 |
| *Carex* sp. (Sedge) | 61.7 | 12.8 | 15.7 | 9.9 | 22.8 |
| *Agrostis gigantea* (Redtop) | 38.3 | 8.0 | 14.2 | 9.0 | 16.9 |
| September 1996: | | | | | |
| *Leersia oryzoides* (Rice cutgrass) | 85.8 | 17.0 | 42.7 | 28.3 | 45.4 |
| *Typha latifolia* (Broad-leaf cattail) | 77.5 | 15.4 | 24.8 | 16.4 | 31.8 |
| *Lythrum salicaria* (Purple loosestrife) | 45.0 | 8.9 | 11.1 | 7.4 | 16.3 |
| *Carex comosa* (Sedge) | 43.3 | 8.6 | 10.3 | 6.8 | 15.4 |

wetland vegetation had successfully established, which is reflected by relatively high species richness and percent total vegetation cover values (Tables 6 and 7).

Annual ryegrass, which is commonly used to restore wetland areas disturbed by pipeline construction, germinated within one week after planting in 1994. Ryegrass did not grow well where soil was inundated. As pooled water dissipated, barren soil was exposed. This soil was quickly colonized by seed and by propagules within the soil. Annual ryegrass grew well and provided a dense vegetation cover in other areas, but, as an annual, was practically non-existent during the second growing season (Table 3). At the end of the 1994 growing season, ryegrass plots had the lowest percent total vegetation cover of the four treatments applied (Table 6). Throughout the 1995 and 1996 growing seasons annual ryegrass plots had total vegetation cover values similar to other treatment types as a result of natural wetland vegetation becoming established within the plots.

Redtop did not provide an initial dense vegetation cover similar to millet or annual ryegrass (Table 4). Average plant height was only 10.2 cm (4 in), as compared to 60 cm (24 in) for millet and 45.7 cm (18 in) for annual ryegrass. Furthermore, redtop did not germinate in areas of pooled water. Although redtop was a slow germinator, and did not attain a luxuriant vegetative cover, plots seeded with redtop had high percent total vegetation cover and species richness values at the time of the fall 1994 sampling. Over the next two growing seasons, redtop plots maintained the highest percent total vegetation cover (97–98%) (Table 6). As a perennial, redtop differed from the other planted grasses by persisting as a dominant species in the latter years of the study.

Untreated control plots were allowed to revegetate naturally, which quickly happened during the first growing season. The source of this vegetation was from viable plant material in the restored topsoil and from the input of seeds from adjacent, undisturbed wetland vegetation. Plots allowed to reseed naturally had high species richness (Table 7) and total vegetation cover values that were initially low, but in latter years similar to plots receiving grass treatments (Table 6).

### Total vegetation cover

In general, vegetation cover ranged from about 46–67% after the first growing season, exceeded about 91% in all treatment plots after the second growing season, and was over 94% after the third growing season (Table 6). These data indicate that total vegetation cover meets typical agency requirements of being in excess of 85% after the second growing season, regardless of grass treatment or even if the disturbed right-of-way was not seeded (untreated control).

### Plant species richness

Plant species richness (number of species) is summarized in Table 7. Species richness values ranged from 10 to 18 among the treatment types after the first growing season, and generally increased with time varying from 25 to 32 after the third growing season. Although millet appeared to out-compete all other species of

**Table 6. Percent total vegetation cover**

| Treatment | Sept. 1994. End of first growing season. Study area | | | | June 1995. Beginning of second growing season. Study area | | | | Sept. 1995. End of second growing season. Study area | | | | Sept. 1996. End of third growing season. Study area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean |
| Japanese millet | 73.3 | 79.8 | 47.9 | 67.0 | 34.7 | 38.1 | 55.4 | 42.7 | 85.5 | 89.3 | 97.8 | 90.0 | 89.5 | 96.3 | 97.0 | 94.3 |
| Annual ryegrass | 53.9 | 58.1 | 25.9 | 46.0 | 66.9 | 70.1 | 66.0 | 67.7 | 100.0 | 98.3 | 97.5 | 98.6 | 93.5 | 94.3 | 98.0 | 95.3 |
| Redtop | 60.1 | 68.4 | 37.8 | 55.4 | 59.8 | 78.3 | 74.6 | 70.9 | 97.8 | 99.0 | 98.8 | 98.5 | 93.4 | 9.5 | 98.3 | 97.1 |
| Untreated control | 64.1 | 53.3 | 28.3 | 48.6 | 62.1 | 52.3 | 70.8 | 61.7 | 98.6 | 99.3 | 95.5 | 97.8 | 95.5 | 95.8 | 97.5 | 96.3 |

**Table 7. Plant species richness**

| Treatment | Sept. 1994. End of first growing season Study area | | | | June 1995. Beginning of second growing season Study area | | | | Sept. 1995. End of second growing season Study area | | | | Sept. 1996. End of third growing season Study area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean |
| Japanese millet | 8 | 8 | 13 | 10 | 14 | 19 | 18 | 17 | 18 | 22 | 26 | 22 | 26 | 30 | 39 | 32 |
| Annual ryegrass | 15 | 15 | 10 | 13 | 22 | 24 | 16 | 21 | 19 | 24 | 15 | 19 | 23 | 25 | 26 | 25 |
| Redtop | 17 | 21 | 15 | 18 | 19 | 23 | 18 | 20 | 16 | 24 | 25 | 22 | 16 | 27 | 37 | 27 |
| Untreated control | 11 | 19 | 16 | 15 | 16 | 26 | 22 | 21 | 15 | 30 | 23 | 23 | 14 | 24 | 38 | 25 |

**Table 8. Importance values for purple loosestrife among treatments**

| Treatment | Sept. 1994. End of first growing season. Study area | | | | Sept. 1995. End of second growing season. Study area | | | | Sept. 1996. End of third growing season. Study area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean | VCN 9N | VCN 9S | VCN 19 | Mean |
| Japanese millet | 5.3 | 0 | 0 | 1.8 | 34.0 | 11.6 | 0 | 15.2 | 40.8 | 30.1 | 0 | 23.6 |
| Annual ryegrass | 23.1 | 5.7 | 0 | 9.6 | 30.2 | 22.0 | 0 | 17.4 | 25.8 | 27.2 | 1.6 | 18.2 |
| Redtop | 13.2 | 3.5 | 1.6 | 6.1 | 29.2 | 19.8 | 2.6 | 17.2 | 27.1 | 26.9 | 1.1 | 18.4 |
| Untreated control | 21.1 | 1.3 | 1.7 | 8.0 | 32.0 | 16.1 | 0 | 16.0 | 30.7 | 20.7 | 2.2 | 17.9 |

**Table 9. Importance values for common reedgrass among treatments**

| Treatment | Sept. 1994. End of first growing season. Study area | | | Sept. 1995. End of second growing season. Study area | | | Sept. 1996. End of third growing season. Study area | | |
|---|---|---|---|---|---|---|---|---|---|
| | VCN 9N | VCN 9S | VCN 19 | VCN 9N | VCN 9S | VCN 19 | VCN 9N | VCN 9S | VCN 19 |
| Japanese millet | 0 | 0 | 0 | 0 | 0 | 0 | 2.4 | 0 | 0 |
| Annual ryegrass | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1.1 | 0 |
| Redtop | 0 | 0.7 | 0 | 0 | 1.4 | 0 | 0 | 0 | 0 |
| Untreated control | 0 | 1.3 | 0 | 0 | 1.3 | 0 | 0 | 2.5 | 0 |

vegetation during the first year, including purple loosestrife and common reedgrass, it also had the lowest species richness (a value of 10). By the end of the second growing season, Japanese millet plots had a species richness that was similar to the other treatments. At the end of the third growing season, Japanese millet plots had the highest species richness, although the values for all treatment plots were not that different. In all other treatment plots, species richness was similar and appeared to increase in a similar manner.

### Purple loosestrife inhibition

Importance value data for purple loosestrife among treatments are presented in Table 8. Purple loosestrife invaded many of the treatment plots, and increased in abundance from 1994 to 1996. By the end of the third growing season (1996) it was evident in nearly all treatment plots.

Japanese millet inhibited the establishment of purple loosestrife in 1994. However, by 1996 the highest purple loosestrife importance value was in the millet plots. In contrast, untreated control plots had the second highest loosestrife importance value at the end of the first year and the lowest by 1996. This indicates that millet is a good initial inhibitor, but not necessarily good in the long term. By 1996, the plots planted with grasses had a slightly higher, although somewhat similar loosestrife abundance, when compared to the untreated plots.

### Common reedgrass inhibition

Importance value data for common reedgrass are presented in Table 9. Most values were zero indicating the absence of reedgrass. Common reedgrass was never an invasive species within wetland study areas during the three-year study, although an abundant seed source was adjacent to all study areas.

### Hydrology

Water levels in wetland study areas appeared to influence the success of different seed treatments and the species composition of the naturally-invading community. Based on field observations, none of the grass treatments did well in areas of pooled water. Millet appeared to grow the best of all the treatments in these areas, with ryegrass growing the worst. In areas of standing water, water purslane and burreed were initial invaders, but total vegetation cover was fairly low in these areas after the first growing season. In the dry, second growing season (1995), rice cutgrass and swamp beggar-ticks were abundant in these areas. Loosestrife abundance was lower in areas of inundation.

## SUMMARY/CONCLUSIONS

It appears that the purchase of seed and labor expense of planting agricultural grasses to reduce the invasion of purple loosestrife and common reedgrass on organic soil wetlands disturbed by pipeline construction is not justified. Our findings are consistent with other research, which has shown that the pulling, mowing, burning, flooding, disking, and applying chemicals to control the establishment of purple loosestrife and common reedgrass are relatively ineffective and expensive (Marks et al. 1994). Biological measures of control are currently being researched and show some promise at controlling these weed species of vegetation, but need to be "fine-tuned" (USDI 1995).

Although seeding disturbed wetland areas is normally required by state and federal permit conditions, a more cost-efficient and biologically effective approach to restoring wetland areas disturbed by pipeline construction where erosion is not an issue is to ensure that wetland topsoil, which harbors seeds and rootstocks of wetland vegetation, be separated from subsoil during excavation and spoiling activities. Then, when backfilling the trench, ensure that topsoil is redistributed across the disturbed area to at, or below preconstruction grade. Restoration below preconstruction grade will likely pool water and inhibit most plantings and the initial invasion of wetland vegetation, which will result in a lower total vegetation cover. However, it may be effective at reducing loosestrife invasion.

Our study demonstrated that wetland areas allowed to revegetate naturally had achieved vegetative cover in excess of 85%, an agency standard, by the end of the second growing season. The source of this vegetation growth was from seeds and other plant material found in the replaced topsoil. These areas also had species richness values that were comparable or higher than those of seeded wetland areas.

Although the seeding of disturbed wetland areas may not be worthwhile in most instances, there are situations where seeding is warranted. If erosion is a concern, seeding would help to stabilize the area. If wildlife food and cover or aesthetics is of interest, the seeding of a species, such as millet, may be beneficial.

Also, it appears that restoration requirements and permit conditions should allow for more flexibility to assess the site conditions and time of year of restoration before prescribing restoration treatments. Such flexibility could reduce restoration costs and increase wetland benefits in the long term.

## ACKNOWLEDGEMENTS

The support provided by Niagara Mohawk Power Corporation throughout this research effort is greatly appreciated.

## REFERENCES

Cox, G.C. 1972. Laboratory Manual of General Ecology. Wm. C. Brown Company Pub., Dubuque, Iowa.

Jones, S.A., M.E. Corey, and L. Zicari. 1983. The wetlands of Oswego County, New York: The interrelationships of glaciation, surficial geologic deposits, and wetland formation. Oswego County Planning Board, Oswego, New York.

Kisslinger, F.E., R.E. Eckert, and P. Currie. 1960. A comparison of line intercept, variable plot, and loop methods as used to measure shrub crown cover. Journal of Range Management, 13: 17–21.

Lindsey, A.A. 1956. Sampling methods and community attributes in forest ecology. Forest Science, 2(4): 287–296.

Marks, M., B. Lapin, and J. Randall. 1994. Phragmites australis (*P. australis*): Threats, management, and monitoring. Natural Areas Journal, 14: 285–294.

TES. 1996. Final Report — Evaluation of different grasses to restore wetlands after pipeline construction and to reduce the occurrence of weed species. Terrestrial Environmental Specialists, Inc. Phoenix, New York.

USDI. 1995. Environmental Assessment. Proposed release of three non-indigenous insects, *Gulerucella calmariensis, Galerucella pusilla,* and *Hylobius transversovittatus* for the biological control of purple loosestrife *(Lythrum salicaria).* U.S. Dept. Interior, Fish and Wildlife Service, Washington, DC.

USSCS. 1981. Soil survey of Oswego County, New York. U.S. Dept. Agric. Soil Conservation Service in Cooperation with Cornell University Agricultural Experiment Station.

## *BIOGRAPHICAL SKETCHES*

***Joseph M. McMullen***

*Terrestrial Environmental Specialists, Inc., 23 County Route 6, Suit A, Phoenix, NY 13135, USA*

Joseph M. McMullen, Principal Environmental Scientist at Terrestrial Environmental Specialists, Inc., has a BS in biology from Saint Francis College and an MS in biology with a concentration in botany from West Virginia University. He has worked for 22 years on all aspects of vegetation and wetland study, including wetlands restoration and numerous projects for electric and gas right-of-way permitting and maintenance.

***Mark E. Burger***

*Terrestrial Environmental Specialists, Inc., 23 County Route 6, Suit A, Phoenix, NY 13135, USA*

Mark E. Burger, Assistant Environmental Scientist at Terrestrial Environmental Specialists, Inc., holds a BS in resource management and an MS in soil science from the SUNY College of Environmental Science and Forestry. At TES, Mark supports staff with wetland delineations and mitigation projects; erosion and sediment control, and vegetation planting. He is currently involved with research on Alternatives to Brushmat Removal after Pipeline Construction.

***Scott D. Shupe***

*Niagara Mohawk Power Corporation, 300 Erie Blvd. West, A-2, Syracuse, NY 13202, USA*

Scott D. Shupe, Environmental Analyst at Niagara Mohawk, holds a B.S. in Biology and a M.S. in Water

Resource Management from SUNY College of Environmental Science and Forestry, and a M.S. in Science Management from the University of Alaska-Anchorage. In consulting, government, and industry, his career has spanned the planning-construction-operations spectrum, including all elements of high-voltage power line construction contract management, small hydropower and navigation planning. He currently supports non-nuclear generation, gas, and electric system operating and licensing groups.

# Consideration of Biodiversity in Rights-of-Way Management by the Utility Industry in Maryland

**Sandra Shaw Patty, Mark T. Southerland, and Stephen D. Kartalia**

The Power Plant Research Program, a division of the Maryland Department of Natural Resources (DNR) is charged with addressing the environmental consequences of electric power generation and transmission within Maryland. Recent results from a survey of U.S. and Canadian utility company biologists indicate that a majority believe biodiversity conservation should be a goal for resource management although it is not currently a major issue for most companies. To address the question of cumulative impacts on biodiversity related to power generation and transmission, the Power Plant Research Program conducted a similar biodiversity survey of public utility commissions and natural resource agencies in all 50 states. The result of our survey of state agencies parallels the results of the survey of utilities. Both surveys found that few states or utilities are directly addressing the biodiversity issue. Both surveys indicated that more than three-quarters of the utilities and state agencies feel that biodiversity will be an important issue in the future. Now, two-thirds of the state agencies, but less than one-quarter of utilities, consider biodiversity an important issue. Similarly, state agencies are more than twice as likely to be conducting or funding research related to biodiversity. This argues for increased attention to biodiversity by electric utilities. It also poses a challenge for state natural resource agencies seeking ways to minimize the adverse effects and maximize the beneficial effects of utilities on biodiversity. As one of very few states with comprehensive state agency management for biodiversity and a program that specifically addresses the environmental impacts of the electric utility industry, Maryland is considering several joint activities with the electric utilities to address biodiversity. Improved siting and management of transmission line rights-of-way are foremost among these.

*Keywords*: Biodiversity, power plants, questionnaire, public utility commissions, state natural resource agencies, ecosystem management, rights-of-way, conservation

## WHAT IS BIODIVERSITY AND WHY SHOULD WE CARE?

There is now a general scientific consensus on a broad definition of biodiversity. Perhaps the best definition is the following version modified from the Keystone Policy Dialogue addressing Biological Diversity on Federal Lands (1991) by Noss and Cooperrider (1994):

> "Biodiversity is the variety of life and its processes. It includes the variety of organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting."

The new focus on biodiversity and its status as a ubiquitous buzzword result from the recognition that projection of the loss of species is great (even in the United States) and that environmental degradation continues in the face of attempts to regulate impacts on a resource by resource basis. The solution to conserving biodiversity is to preserve and restore natural ecosystems with enough native components to sustain themselves over time. The scientific community asserts that biodiversity should be conserved at four scales (levels of organization): genetic, species, ecosystem, and landscape (Office of Technology Assessment 1987, Council on Environmental Quality 1993). The primary conservation goals at the larger geographic scales are (1) representing all native ecosystems in a network of protected areas and (2) maintaining complete, unfragmented environmental gradients. Arguments defending biodiversity focus on four kinds of values:

- utilitarian values (medicinal uses of plants, agricultural gene stocks, fisheries as a food source),
- indirect utilitarian values (ecosystem services such as air quality, climate amelioration, flood regulation, soil building, waste assimilation, pest control, crop pollination),
- recreational and aesthetic values, and
- intrinsic, spiritual, and ethical values.

Each of these values has strong support in the general population. Surveys indicate that two-thirds of the population support the preservation of endangered species over immediate job creation. Perhaps the most strongly held belief is that of intergenerational equity, i.e., the public expects natural resource agencies to provide natural areas for future generations.

The Maryland Department of Natural Resources (DNR) is committed to conserving biodiversity as part of its mission and has formed an Ecosystem Council with the following goals (Maryland DNR 1996):

- a shared understanding of ecosystem management principles among DNR staff,
- recognition of the Maryland DNR as a leader in scientifically-based ecosystem management,
- diverse information available and shared between resource professionals and partners,
- a continuous flow, compilation, analysis, interpretation and distribution of pertinent ecological data,
- a network of core protected lands that represent Maryland's native biological diversity,
- incorporation of ecosystem management principles into local government policies and initiatives, and
- Marylanders live in harmony with their environment.

To reach these goals, the Maryland DNR is reevaluating each of its programs and activities to determine if they can make a significant contribution to conserving biodiversity. To that end, the Power Plant Research Program of the Maryland DNR is investigating ways that it can minimize the adverse effects and maximize the beneficial effects on biodiversity of the electric utility industry in the State.

## BIODIVERSITY AND THE ELECTRIC UTILITY INDUSTRY

On 19–20 March 1996, the Electric Power Research Institute (EPRI) sponsored a conference entitled, *Managing for Biodiversity: Emerging Ideas for the Electric Utility Industry*. More than 100 individuals from 80 different agencies and companies attended. The goals of the meeting were to

- identify and understand biodiversity issues for electric utilities;
- develop new insights from current biodiversity research and case studies; and
- catalyze partnerships among utilities, state and federal regulatory agencies, public interest groups, and academic scientists to build policies, regulations, and decision strategies for biodiversity that will serve the interests of the entire community.

The conference presented case examples of utilities working to conserve biodiversity (or related natural resources) and commentary by experts on how the industry should address biodiversity. One of the most important areas where utility activities could have both adverse and beneficial effects on biodiversity is the management of rights-of-way. The conference consensus was that the electric utility industry should be, can be, and is conducting some "beyond compliance" projects to conserve aspects of biodiversity. At the same time, many utilities indicated that implementing additional measures to conserve biodiversity would be problematic given current and future funding constraints.

During this conference, Breece and Ward (1996) described a survey of U.S. and Canadian utility companies that they conducted on the subject of biodiversity. They found that although many utility biologists felt that conserving biodiversity was likely to become a major issue in the future, only a few were currently addressing it. This raises the question of how state public utility commissions and natural resource agencies view the importance of considering biodiversity impacts of electric utility activities. To answer that question, the Maryland DNR's Power Plant Research Program implemented a survey of public utility commissions and natural resource agencies in all 50 states. The rest of this paper presents the results of this biodiversity survey and describes activities that the Power Plant Research Program is considering to address the effects of the utility industry on biodiversity in Maryland.

## HOW WE CONDUCTED OUR STATE SURVEY ON BIODIVERSITY

In the fall of 1996, the Power Plant Research Program surveyed the public utility commissions (PUCs) and relevant natural resource agencies in all 50 states. One hundred (100) individuals were mailed a 3-page survey (see Fig. 1) and asked to complete and return it via postage-paid envelope, fax, or Internet. We provided a web site for that purpose and listed the site address in the mailing. The purpose of the survey was to answer the following questions:

- How do other state agencies define biodiversity?
- Do they think the effect of electric utility activities on biodiversity is important and, if so, what are they doing about it?
- How important do they believe considering the effects of electric utility activities on biodiversity will be in the future?
- How do Maryland's current and future plans for addressing the effects of electric utility activities on biodiversity compare with other states?

**BIODIVERSITY ISSUES FOR ELECTRIC UTILITY FACILITIES**

PLEASE RETURN THE QUESTIONNAIRE BY NOVEMBER 30, 1996 TO:

Steve Kartalia
Versar, Inc.
9200 Rumsey Road
Columbia, Maryland 21045-1934
tel: 410-740-6080
fax: 410-964-5156
internet: kartaliaste@versar.com

**AGENCY QUESTIONNAIRE:**

1. Does (FIELD(State)) exercise regulatory authority over construction of new electric utility facilities? Y___ N___

   If yes, what parameter(s) are regulated?

   ___ Pre-Construction approval
   ___ Need
   ___ Cost
   ___ Socioeconomic impacts
   ___ Environmental impacts

2. Does your agency have a division or section whose specific purpose is to assess the environmental impacts of electric utility facilities? Y___ N___

   If yes, which divisions are involved in reviewing and assessing power plant projects?

3. Do you know of any other agencies in your state that address the ecological impacts of power plants?

4. Does your agency consider biodiversity when it assesses the impacts of power plants?

5. How do you define biodiversity?

6. What other environmental issues does your agency address in a typical licensing procedure (check all that apply)?

   ___ wetlands
   ___ endangered species
   ___ habitat loss
   ___ habitat fragmentation
   ___ air quality
   ___ water quality
   ___ cultural resources
   ___ aesthetic resources
   ___ other (please list)

7. Does your agency use specific criteria for assessing impacts to biodiversity?
   Does your agency use quantitative criteria or models for these assessments?
   List the criteria or models you use

   e.g., Models: Habitat Evaluation Procedures — Criteria: the loss of habitat units

8. Does your agency <u>require</u> or <u>recommend</u> (circle one) mitigation for impacts to biodiversity? If so, how is the amount and type of mitigation determined?

9. Does your agency encourage partnerships between utilities and citizen groups to mitigate for impacts to biodiversity? Which ones?

   ___ Audubon Society
   ___ Bassmasters
   ___ Buckmasters
   ___ Ducks Unlimited
   ___ Izaak Walton League
   ___ Sierra Club
   ___ Trout Unlimited)
   ___ Wildlife Federation
   ___ Wildlife Society
   ___ Other (please list)

10. What types of biodiversity issues is your agency most concerned with (check all that apply):

   __ power plant siting
   __ land management
   __ cumulative effects mitigation (e.g., carbon sequestering by reforestation)
   __ impact avoidance
   __ impact mitigation

   __ wetlands
   __ terrestrial species
   __ aquatic species
   __ marine species
   __ hydro relicensing
   __ rights-of-way maintenance and construction
   __ reservoir management
   __ endangered species management
   __ power plant operations

11. How important, as a future issue, will biodiversity be to your agency?

   a. a major issue
   b. may become an issue
   c. no opinion
   d. probably not an issue
   e. will not be an issue

12. Does your agency fund and/or conduct research on biodiversity? ecosystem management? sustainable use? Please elaborate.

13. Are there any other comments you would like to provide?

Fig. 1. Questionnaire.

## RESULTS OF OUR STATE SURVEY ON BIODIVERSITY

Forty of the 100 questionnaires mailed to the states were returned. This 40% response rate is the same as that obtained by Breece and Ward in their survey of utilities. Of these 40, 33 responded by mail, seven by fax, and none via the Internet. PUCs were more likely to respond to the survey than state resource agencies (23 of 50 versus 17 of 50).

State natural resource agencies were more likely than PUCs to respond that biodiversity will be an issue in the future (82% responded that it may become an issue compared to 27% for PUCs). In Breece and Ward's survey, 76% of utilities responded that biodiversity will likely become a major issue in the future.

Most respondents do not have a division whose specific purpose is to review power plant impacts (73%). If one does exist, it is more likely to be part of a state natural resource agency than a PUC (38% of state natural resource agencies compared with 18% of PUCs).

**Responses to Key Survey Questions**

Does your agency have a division or section whose specific purpose is to assess the environmental impacts of power plants?

| | Yes | No | NR |
|---|---|---|---|
| PUCs | 4/23 | 19/23 | 0/23 |
| DNRs | 7/17 | 9/17 | 1/17 |

Does your agency consider biodiversity when it assesses the impacts of power plants?

| | Yes | No | NR |
|---|---|---|---|
| PUCs | 3/23 | 19/23 | 1/23 |
| DNRs | 11/17 | 4/17 | 2/17 |

How important, as a future issue, will biodiversity be to your agency?

| | Major issue | May become | No opinion | Probably not | Will not | NR |
|---|---|---|---|---|---|---|
| PUCs | 3/23 | 3/23 | 3/23 | 7/23 | 0/23 | 7/23 |
| DNRs | 8/17 | 6/17 | 0/17 | 1/17 | 0/17 | 2/17 |

Does your agency fund and/or conduct research on biodiversity, ecosystem management, or sustainable use?

| | Yes | No | NR |
|---|---|---|---|
| PUCs | 1/23 | 21/23 | 1/23 |
| DNRs | 9/17 | 7/17 | 1/17 |

Fig. 2. Responses

Few PUCs (18%) responded that they consider biodiversity when they assess power plant impacts. In contrast, most (65%) state natural resource agencies responded that they consider biodiversity. In Breece and Ward's survey, 22% (24 of 91) of utilities that have environmental policies responded that they address or mention biodiversity in these policies.

Only 5% of PUCs (in our sample, only California) conduct or fund research on biodiversity, ecosystem management, or sustainable use, whereas 53% of the state natural resource agencies responded that they do. In Breece and Ward's survey, only 19% of utilities said they were involved in research, but 59% felt that industry should be more involved with biodiversity research.

Most respondents provided additional comments not specifically asked for in the questionnaire. A few states felt that the terms biodiversity and ecosystem management were difficult to address because they mean different things to different people. Other states have strongly embraced biodiversity conservation and are either modifying agency rules (Ohio), developing biodiversity programs (Nevada), producing biodiversity reports (Missouri), or implementing interagency biodiversity planning (California).

Figure 2 presents responses to some of the key survey questions.

## WHAT DO THESE RESULTS TELL US?

*How do other state agencies define biodiversity?* In our survey, state agencies indicated that they generally subscribe to the scientific consensus on the definition of biodiversity as the full range of variation in native organisms and natural processes. As a practical matter, many existing programs on the protection of specific wildlife species and their habitats are included under the definition of biodiversity. States, such as Maryland, that are integrating ecosystem management into agency operations that focus most directly on biodiversity.

*Do they think the effects of electric utility activities on biodiversity is important and if so what are they doing about it?* The results of our survey of state agencies parallel the results of the Breece and Ward (1996) survey of utilities. Both surveys found that few states and utilities are directly addressing the biodiversity issue. In both cases, the survey results may have overestimated the degree to which biodiversity is being addressed, because agencies that are not addressing biodiversity at all may be less likely to respond.

Our survey results are also consistent with a recently published study by the Defenders of Wildlife (1996) entitled, *Saving Biodiversity: A Status Report on State Laws, Policies and Programs*. In this study the Center for

Wildlife Law and Defenders of Wildlife drew from a variety of information sources to characterize the status of biodiversity policy and biodiversity science within all 50 states. The study listed the provisions for addressing biodiversity in the areas of biodiversity policy, biodiversity science, endangered species laws, state agency management for biodiversity, impact assessment, habitat acquisition, exotic species, animal damage control, additional legal protections for biodiversity, and related issues. Only four states have biodiversity policies and five have comprehensive programs for biodiversity science. Only Maryland and Wyoming have comprehensive state agency management for biodiversity. In the area of impact assessment of biodiversity, 14 states have "little NEPA laws" requiring assessment of state actions. Six states also have documented impact assessment requirements for transmission line siting, hydropower development, or other electric utility related activities.

*How important do they believe considering the effects of electric utility activities on biodiversity will be in the future?* A comparison of the three studies shows that more than three-quarters of both utilities and state agencies feel that biodiversity will be an important issue in the future. While less than one-quarter of the utilities currently consider biodiversity an Important issue, two-thirds of the state agencies consider it an important issue. Similarly, state agencies are more than twice as likely to be conducting or funding research on biodiversity related issues.

*How do Maryland's current and future plans for addressing the effects of electric utility activities on biodiversity compare with other states?* Many states are beginning to address biodiversity and ecosystem management, but few are implementing such programs. Maryland is one of only two states with comprehensive state agency management for biodiversity. Maryland is also in the unusual position of having a division of the DNR that specifically addresses the environmental impacts of the electric utility industry, the Power Plant Research Program. The California Energy Commission, a unit of The Resources Agency, was the only similar entity responding to the survey. Therefore, Maryland can proactively evaluate the effects of electric utility activities on biodiversity and encourage management measures to enhance biodiversity.

## WHAT IS MARYLAND DOING TO ADDRESS BIODIVERSITY?

As part of the agency wide ecosystem approach, the Power Plant Research Program is looking at ways to work cooperatively with the utility industry to improve management for biodiversity. The siting and management of transmission line rights-of-way are an important area for this cooperation. The Power Plant Research Program is considering undertaking the following joint activities with the electric utilities to address biodiversity.

### Biodiversity guidance for utilities

The Power Plant Research Program could develop guidance for utilities to manage lands, avoid adverse biodiversity impacts, and undertake mitigation for enhancing biodiversity. This could draw on general scientific principles (e.g., Council on Environmental Quality guidance for considering impacts) and approaches offered in the DNR Ecosystem Management initiative. The Power Plant Research Program would also coordinate with other state agencies to define statewide biodiversity goals.

### Biodiversity issues related to transmission line rights-of-way

The Power Plant Research Program could undertake a specific research project to determine the impacts of habitat fragmentation caused by transmission lines on biodiversity in Maryland. Specifically, the Power Plant Research Program could conduct a joint project with the Patuxent Wildlife Research Center that draws upon existing rights-of-way research, the NBS Breeding Bird Survey data, Maryland Gap analysis project, threatened and endangered species data and the Maryland Biological Stream Survey data. The analytical step would be overlaying these biological data on the Power Plant Research Program's newly developed GIS of Maryland transmission line corridors.

### Biodiversity issues related to hydropower facilities

To date, restoration of the Susquehanna River has focused solely on anadromous fish species. This ignores the obvious losses of riffle habitat for native species in the impoundments. The Power Plant Research Program could raise the biodiversity issue on the Susquehanna and conduct an assessment to learn if it is an issue to be pursued.

### Biodiversity hotspots for use in power facilities siting

Arguably the most important biodiversity issue for the Power Plant Research Program is reducing the adverse impacts on biodiversity of siting of new electric power facilities. Maps of high species richness and distributions of rare species are critical to developing the ecological siting criteria needed to minimize biodiversity impacts. The Power Plant Research Program could take the lead in developing these siting criteria by creating biodiversity hotspot maps using Maryland Biological Stream Survey data, Gap Analysis Project and terrestrial inventories from the Heritage and biodiversity conservation programs.

### Methodology to address cumulative impacts to biodiversity

The interconnected nature of biodiversity means that it is affected by many anthropogenic activities, including those of the electric utility industry. Even facilities that meet all existing permitting and license provisions still discharge various materials into the environment and create small, legally acceptable environmental perturbations that cumulatively affect biodiversity. Therefore, a comprehensive methodology for addressing the cumulative impacts of power generating and transmission facilities on the landscape scale is needed. The Power Plant Research Program could take the lead in developing a cumulative impact methodology for biodiversity by focusing on power plant effects and developing methods (e.g., GIS tools) for evaluating them in the context of other activities in the watershed or landscape.

## ACKNOWLEDGMENTS

The authors would like to thank the following entities for their assistance and participation in this study: Versar, Inc. Staff; EPRI Staff; personnel from the various States that took the time to respond to our questionnaire. Without your responses, this paper could not have been completed.

## REFERENCES

Breece, G.A. and B.J. Ward. 1996. Utility terrestrial biodiversity issues. Environmental Management, 20(6): 799–803.

Defenders of Wildlife. 1996. Saving biodiversity: A status report on state laws, policies, and programs. Washington, D.C.

Maryland Department of Natural Resources (DNR). 1996. Ecosystem management: Findings of the Ecosystem Council and interim report to the Secretary of Natural Resources. Ecosystem Council, Maryland Department of Natural Resources, Annapolis, Maryland. 11 March.

Council on Environmental Quality (CEQ). 1993. Incorporating biodiversity considerations into environmental impact analysis under the National Environmental Policy Act. Executive Office of the President, Washington, D.C. 29 pp.

The Keystone Center. 1991. Biological diversity on Federal lands: Report of a Keystone Policy Dialogue. Keystone, Colorado. 96 pp.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving Nature's Legacy. Island Press, Washington, D.C. 380 pp.

Office of Technology Assessment (OTA). 1987. Technologies to maintain biological diversity in the United States. Congress of the United States, Washington, D.C.

## *BIOGRAPHICAL SKETCHES*

***Sandra Shaw Patty***

*Maryland Department of Natural Resources, Power Plant Assessment Division, Tawes State Office Building, B-3, Annapolis, MD 21401-2397, USA*

Sandra Shaw Patty is an Energy Resources Manager for the Maryland Department of Natural Resources, the Power Plant Research Program. In this position she serves as the transmission program manager, responsible for conducting studies assessing all aspects of the electric transmission network in Maryland. Ms. Patty is responsible for defining pertinent issues and evaluation of studies and analyses necessary to provide a comprehensive assessment of environmental and socioeconomic impacts associated with the construction and operation of electric facilities. The Department of Natural Resources and other state agencies use the results of her assessments in licensing and administrative proceedings for power stations and transmission lines. Before joining PPRP Ms. Patty was employed by Allegheny Power Systems as an Environmental Analyst from 1974 to 1991. She received her B.S. in Biology from California State College in 1973, and a Masters of Energy Resources from the University of Pittsburgh in 1983.

***Mark T. Southerland***

*Versar, Inc., 9200 Rumsey Road, Columbia, MD 21045-1934, USA*

Mark T. Southerland is a senior ecologist at Versar, Inc. He has coauthored guidance on the conservation of biodiversity for the Council on Environmental Quality, U.S. Environmental Protection Agency, and Federal Energy Regulatory Commission. His education includes a B.A. in zoology from Pomona College, a Ph.D. in ecology from the University of North Carolina at Chapel Hill, and a Postdoctoral Fellowship at the Smithsonian Environmental Research Center.

***Stephen D. Kartalia***

*Versar, Inc., 9200 Rumsey Road, Columbia, MD 21045-1934, USA*

Stephen D. Kartalia is an environmental biologist at Versar, Inc. with interests in fisheries management and aquatic ecology. He has a B.S. in biology from Wake Forest University and an M.S. in fisheries from Clemson University.

# Part VIII
# Geographic Information Systems

# GPS Guidance System for Right-of-Way Aerial Spraying of Phytocides

**Jean Domingue and Jean Turbide**

Vegetation control in remote powerline rights-of-way of northeastern Québec requires innovative methods that need to be efficient and environmentally sound. To fulfill these needs, a herbicide spraying technique was developed using high technologies such as GPS positioning, computer assisted photogrammetry, telemetry and computer assisted drawing. The use of a GPS guidance system in conjunction with a delay calculation module to open and close nozzles significantly increased the ground precision of the spray. In field conditions on a rugged terrain, the spray beyond the buffer zones was 8 m or less in 92% of the time and was less than 14 m in 99% of the time ($n$ = 148 buffer zones). This technology appears promising and proves to be an efficient technique for vegetation control in powerline rights-of-way.

*Keywords:* Aerial spraying, automatic nozzles, GPS guidance system, Québec, right-of-way, Tordon 101

## INTRODUCTION

Vegetation control in remote powerline rights-of-way of northeastern Québec requires innovative and cost-effective methods that need to be efficient and environmentally sound. Aerial spraying is often a cost-effective approach when large or remote areas have to be treated. However, conventional aerial spraying is often associated with drifting of pesticides and, for this particular reason, the technique cannot be used in the vicinity of environmentally sensitive areas.

To solve this problem, Hydro-Québec, in collaboration with Naturam Environnement Inc., has developed a herbicide spraying technique that significantly reduces drifting while remaining cost-efficient and environmentally safe. This technique relies on several high technologies: GPS positioning, computer assisted photogrammetry, telemetry and computer assisted drawing. The objectives of this vegetation control method, still under development, were: (1) to improve the efficiency of vegetation control in order to assure the network security, by maintaining or establishing low and compatible vegetation communities, and (2) to reduce operational costs in remote areas while maintaining the same level of environmental concerns.

## METHODS

The approach can be subdivided into three main operational blocks: (1) identification of sites for treatment, (2) use of a GPS guidance system and automated spraying system to maximize the precision of treatments, and (3) use of an automated station for constant monitoring of meteorological data (Fig. 1).

### Identification of sites for treatment

Rights-of-way scheduled for treatment are photographed at a 1:2000 scale using an infra-red film. Based on preliminary works we have conducted, topographic maps at a 1:50 000 scale cannot be used with sufficient accuracy, when locating tower structure for example, and they can induce coordinate error of up to 100 m. Therefore, we had to rely on aerial photographs for better precision. These aerial photographs are analyzed by photogrammetry to delineate precisely the areas selected for vegetation control, and to localize all sensitive areas and their adjacent buffer zones. Most of these sensitive areas consist of small streams with a width of 3 m or less. For each sensitive area, a 60 m untreated buffer zone is used to protect water quality.

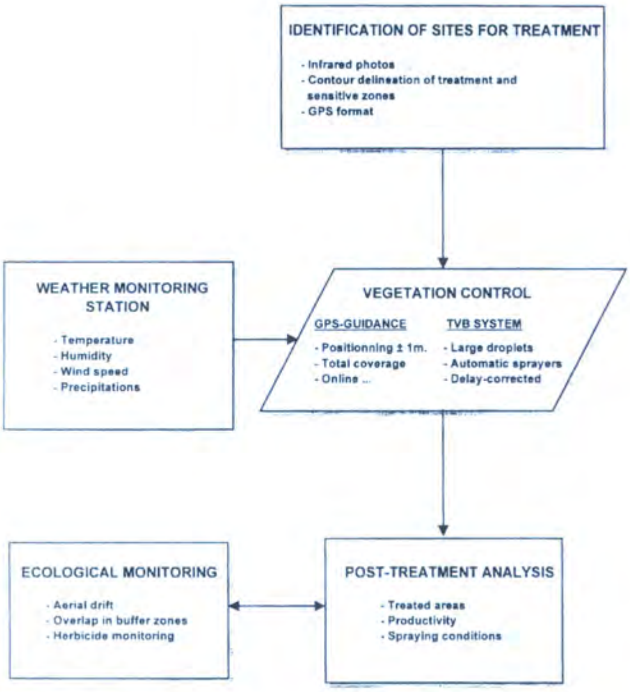



Fig. 1. Flow chart of the different steps involved in aerial spraying of herbicides in Hydro-Québec powerline rights-of- way.

The final polygon mosaic is composed of areas for vegetation control intersperse with sensitive and buffer zones. These polygons are georeferenced using the powerline towers on the infra-red photos as bench marks. The data set is finally recoded into a format compatible with a GPS guidance system.

### GPS guidance system.

The GPS guidance system is made up of three components: a GPS unit (AGNAV P-111, Picodas Group, Richmond Hill, Ontario), a receiver for differential correction, and a delay calculation module. The first two units determine the exact position of the helicopter five times per second. The third unit controls the spraying system. The main unit integrates the block coordinates while the GPS system provides the exact location of the helicopter. A monitor in the helicopter indicates the progression of the work by illustrating the sprayed area.

Nozzles are opened and closed automatically by a unit that makes all the necessary delay calculations, according to helicopter altitude, speed, time to build up the required pressure in the spraying system. The sprayed area is real-time displayed on the monitor and all data are stored on a hard disk. Data can later be retrieve for post-treatment mapping and analysis (Fig. 2). The Thru-valve boom spraying system produces large droplets of Tordon 101 (DowElanco, Calgary, AB) which are less prone to aerial drift. By using the GPS guidance system in conjunction with the delay calculation module, herbicide droplets can reach the ground with a high precision. This system also ensure an adequate overlap between each sprayed transect for total ground coverage.

### Automated weather monitoring station

A portable weather station (Fig. 3) is installed in the ROW to radio-transmit local meteorological conditions at treatment sites: temperature, relative humidity, wind speed and direction, barometric pressure and precipitation. This weather station can easily and safely be slung by helicopter as the treatment progresses. The weather station transmits data every 30 seconds to the herbicide mixing station and the base camp. Data can be viewed instantly on line or users can obtain a summary of the past 6 hours of data recording. Due to the high variability of weather conditions at a micro-scale

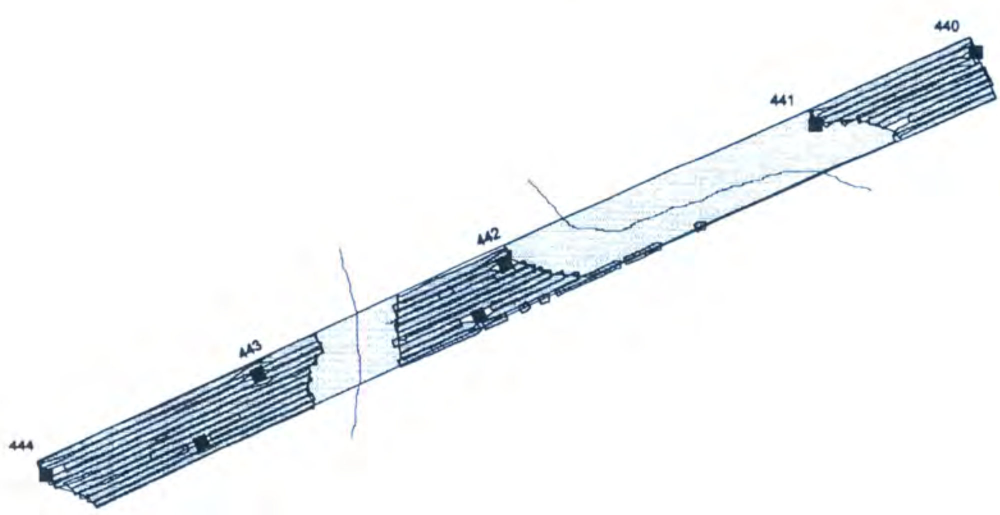



Fig. 2. Example of a post-treatment analysis between towers 440 and 444 in a powerline right-of-way. Black squares correspond to tower location, shaded areas are buffer zones adjacent to streams (black lines), treated areas are represented by the long and narrow rectangles.

Fig. 3. Portable weather monitoring station used during spraying operations to transmit weather conditions.

(caused by altitude, valley orientation, etc), this portable station enables the field crew to know weather conditions prior to treatment. This allows respect of all relevant environmental conditions during spraying and saves a lot of time.

## RESULTS AND DISCUSSION

The system was calibrated in controlled experimental conditions where topography was flat for easy helicopter access and in the absence of electrical towers (Fig. 4). Bands of water sensitive paper were aligned on the ground to measure off target distances of herbicide deposition. In summer 1996, the GPS-guidance and spraying systems were field tested on a rugged terrain, in 735 kV powerline ROWs where conductor/ground clearance was between 13 and 25 m (40–80 ft).

Under controlled experimental conditions, ground precision of the GPS-guidance system was about 1 m. This precision was achieved by fine-tuning all components of the system (ex. GPS receivers, delay calculation module), and this precision was maintained throughout the final testing steps.

Under field-testing conditions, where electrical towers, conductors, and ground vegetation were present (Fig. 5), herbicide deposition within the buffer zones was 8 m or less in 92% of the time (Fig. 6) and was less than 14 m in 99% of the time ($n$ = 148). The maximum recorded was 21 m in only one instance. All sensitive areas were therefore totally protected from the herbicide by the experimental buffer zones (60 m wide).

From an operational point of view, the system was also efficient. During the 1996 spraying campaign, field productivity was estimated at 7 ha/hour. This estimate includes refueling of helicopter (fuel and herbicide), and transportation time between treatment sites and the mixing station.

This technology appears promising since this kind of precision has never, to our knowledge, been attained

Fig. 4. Aerial spraying in controlled experimental conditions.

Fig. 5. Vegetation in a powerline right-of-way after an aerial spraying of Tordon 101.

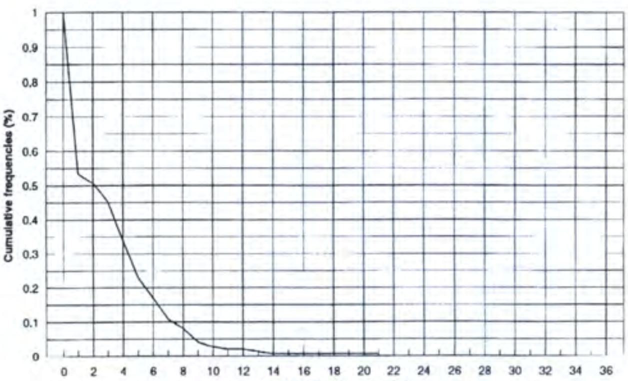



Fig. 6. Occurrence of overlap in buffer zones during aerial spraying of Tordon 101 using a GPS guidance system in 1996.

before during aerial spraying of herbicides. In the actual context where financial resources are limited but environmental concerns are growing, this high-tech system proves to be an efficient approach for vegetation control in remote powerline rights-of-way. Moreover, this approach seems environmentally safe since no quantifiable herbicide was detected in small streams protected by buffer zones during a post-treatment monitoring study (Garant et al. 1995).

## REFERENCES

Garant, Y., J.-L. Poey, and J. Domingue. 1995. Suivi des phytocides dans le milieu naturel. Programme de pulvérisation aérienne de Tordon 101 dans les corridors de transport d'énergie d'Hydro-Québec, 1995. Naturam Environnement. 37 pp.

## *BIOGRAPHICAL SKETCHES*

***Jean Domingue***

*Naturam Environnement, 31 rue Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*

Jean Domingue is president and director of Naturam Environnement Inc. since 1985, a consulting firm specialized in Biology, Forestry, and Environment. His areas of interest are diverse and include application of high-technology in resource management, vegetation maintenance in utility rights-of-way, industrial monitoring and impact assessments.

***Jean Turbide***

*Hydro-Québec, Unité de Maintenance Transport, Manicouagan ouest, 135 Boul. Comeau, Baie-Comeau, Québec, Canada, G4Z 2L6*

Jean Turbide has been working as a forestry technician at Hydro-Québec for the past 15 years. He is responsible of vegetation control in 28 000 ha of powerline rights-of-way in the Manicouagan region, northeastern Québec. Mr. Turbide has participated in several technical innovations in the course of his duties. Over the years, he has developed an adaptive vegetation management approach, by using control methods suited to field conditions.

# Geographic Information Systems (GIS) and Remote Sensing (RS) Applications for the Selection and Environmental Evaluation of High Voltage Transmission Line Rights-of-Way in Colombia

**Luis Fernando Cadena, Bernardita Calinao, Alvaro Torres, and Fernando Anzola**

The Interconexión Electrica S.A. (ISA) — a state-owned company whose principal business in Colombia is planning, constructing and operating the national electrical transmission system, through energy generated from thermal and hydroelectric power plants — is among the companies in the country reflecting an increasing concern and protection for the environment. ISA's identification of optimal routes for high voltage transmission lines, for example, involves not only engineering and cost criteria but also environmental and socio-cultural criteria. This integrated analysis has been successfully achieved through the application of geographic information systems (GIS) and remote sensing (RS) technology during the route selection. GIS and remote sensing for route selection have been applied over the last five years for a combined total of 945 km for three major transmission lines crossing diverse physiographic conditions. In the course of the projects, two GIS technologies (ILWIS and ARC/INFO) were employed for route selection and two remote sensing technologies (Spot Images and Satellite Images through ERDAS) were likewise applied. This paper will describe the application of GIS and remote sensing technology in two of ISA's projects involving route selection, environmental sensitivity analysis and monitoring of transmission line rights-of-way. The result of the application is the integration of environmental with engineering processes, improved environmental evaluation procedure and the consequent formulation of more appropriate environmental controls. Following construction, GIS also serves as a useful tool for the purpose of environmental monitoring, implementation of the environmental management plan and decision making.

*Keywords*: Satellite images, route selection, environmental sensitivity analysis, environmental-electrical engineering design, low, moderate and high ecological and/or social aptitude, entity/relation model

## INTRODUCTION

The Interconexión Electrica S.A. (ISA), a state owned company whose principal business in Colombia is planning, constructing and operating the national electrical transmission system, is among the companies in the country showing greater concern for protecting the environment. ISA's selection of optimal routes for high voltage transmission lines, for example, incorporates engineering, cost and environmental and socio-cultural criteria. This has been successfully achieved through the application of geographic information systems (GIS) and remote sensing (RS) technology during the route selection of transmission lines rights-of-way.

A geographic information system (GIS) is defined as "a set of software tools, hardware, geographic data and personnel designed for capturing, storing, updating, manipulating, analyzing and displaying every form of geographically-referenced information." (ESRI 1994).

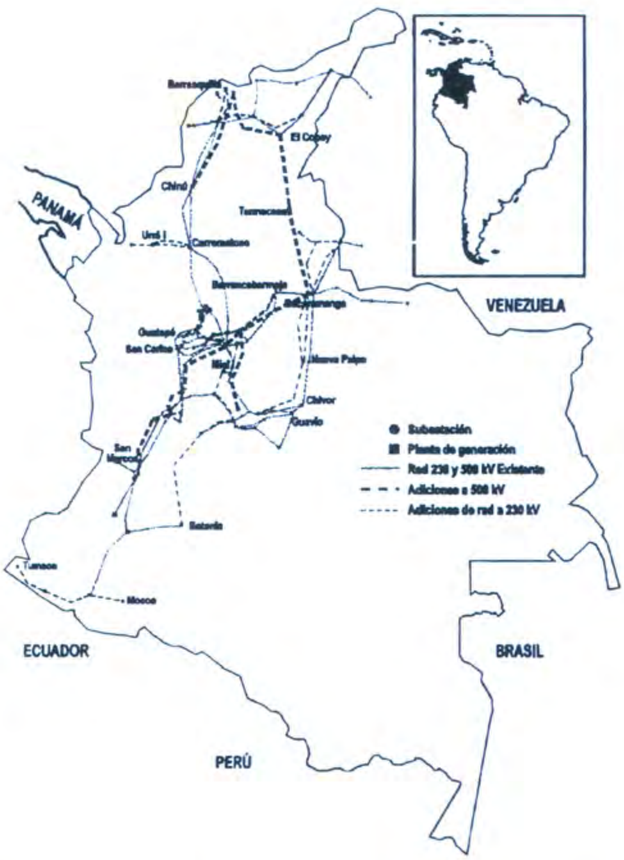



Fig. 1. Expansion network 1997–2006 of Colombian interconnected transmission system. The map shows actual and future network of 230 and 500 kV transmission lines of the National Interconnected System (NIS). ● Transmission substations; ■ power plants. ——: 230 and 500 kV actual lines; ———: 500 kV future lines; - - - - : 230 kV future lines.

Remote sensing technology refers to satellite and radar images which are becoming increasingly important tools of information technology because of the growing need for more precise and efficient interpretation and visual representation of information in environmental and engineering studies (Bell 1995).

Two examples of GIS and remote sensing applications are presented in this article:

(a) the 500 kV transmission line extending approximately 380 km from San Carlos (Antioquia) to San Marcos (Valle del Cauca) carried out from 1994 to 1995, and

(b) the Paipa–Bucaramangga 230 kV transmission line, 200-km long, carried out between 1995 and 1996. For purposes of the route selection, both corridors were assigned an approximate width of 30 km.

The unique environmental and sociocultural conditions combined with the newly created environmental laws of Colombia make environmental work difficult and demanding. Corridor-type projects such as transmission lines which must cross diverse ecosystems and ethnic groups make the task even more challenging. Colombia is among the 12 countries in the world, ranking only second to Brazil, identified as possessing significant mega-biodiversified ecosystems. Its total land area, which represents 0.04% of the world's land surface, contains 10.0% of the world's flora and fauna.

The Natural Parks System of Colombia with its 43 units of parks, sanctuaries for flora and fauna, natural areas and reserves covers a total area of approximately nine million hectares. The ethnic population which is approximately 600,000 (2% of the national population) is divided into 81 ethnic groups and is spread in more than 400 reservations covering a total area of 27.6 million hectares which translates to approximately 24% of the national territory (Pineda and Rummenhoeler 1995).

Figure 1 identifies the current and projected network of electrical transmission lines in Colombia through the year 2006. In general, a period of about 3–5 years can take place between initiating a project to actually energizing the line.

Environmental studies for transmission lines design is recent in the Colombian electrical sector. ISA has organized concurrent-type designs by establishing a cross disciplinary working system among technicians, planners and environmental experts in order to identify proposed transmission line rights-of-way with minimal environmental impacts and maximum regional benefits. Table 1 illustrates the parallel working relationships between the technical and environmental group for the projects.

**Table 1. Basic environmental processes where GIS plays a key role in concurrent planning and design**

| Engineering process | Environmental process |
|---|---|
| Pre-selection of corridor | The determination of Environmentally Restricted Areas (e.g. natural parks, forest reserves) is simultaneously conducted during preselection of corridor. The GIS helps in providing better criteria in the creation of ISA's National Electric Expansion Plans which avoids highly sensitive and fragile ecosystems |
| Route selection | The Environmental Analysis of Alternatives through which the most environmentally viable route is selected is conducted during route selection process. This is best achieved with the aid of remote sensing technology. |
| Design | The preparation of the Environmental Impact Assessment for the selection of the final route is conducted in simultaneous fashion as the engineering design phase. Besides characterization of environmental components and the evaluation of impacts, the development of an environmental plan is also accomplished. |
| Operation and maintenance | During operation and maintenance of the powerlines, ex-post evaluations and the implementation of environmental management program are conducted. |

## OBJECTIVES

The principal objective of this paper is to present a new conceptual and methodological framework for the environmental analysis, route selection and design of electrical transmission line projects through (a) the application of an image interpretation system to facilitate environmental characterization within a regional context, and (b) the application of a geographic information system to achieve greater precision in the environmental evaluation process.

In conformity with Colombian Law No. 99 of 1993, ISA has cooperated with the Ministry of Environment to accomplish the *analysis of environmental alternatives* and the *evaluation of environmental impacts* of high voltage transmission lines projects. These two studies are required prior to obtaining construction approval. In order to comply with the above mentioned environmental law, the objectives of corridor studies are:

- To characterize, at regional scale, the existing environmental conditions in the project area in order to identify sectors that are ecologically and/or socially sensitive to construction and operation impacts. This objective is achieved with satellite image interpretation.
- To apply GIS for analyzing alternatives and selecting the optimal transmission line route based on technical, environmental and sociocultural criteria.
- To identify sociocultural, economic and ecological effects of the project which serves as useful preliminary information for the subsequent impact evaluation study.

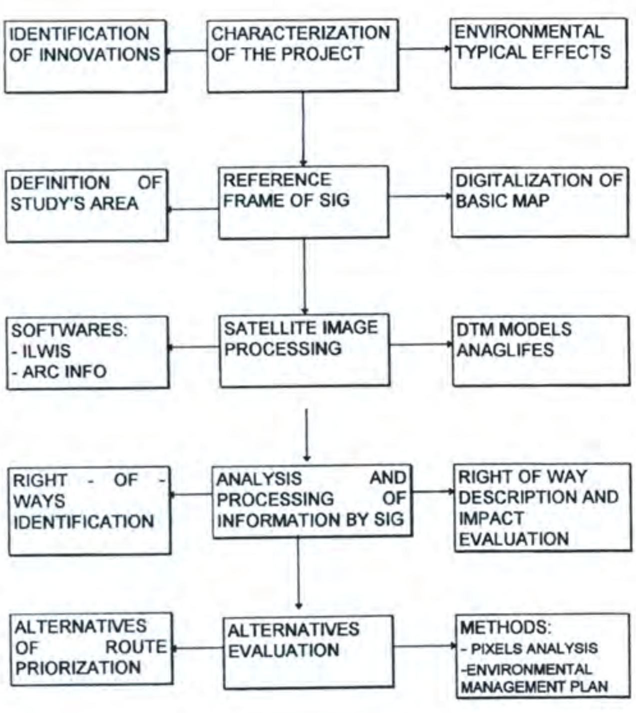



Fig. 2. Methodological sequence of GIS uses.

Accomplishment of these objectives is reflected in the selection of the optimal alternative characterized both in graphic (scale 1 cm:1 km) and non graphic form, the development of an environmental data base for subsequent impact evaluation, and the realization of concurrent environmental-electrical engineering design.

## METHODOLOGY

GIS and remote sensing have been successfully applied over the last five years for a combined total of 945 km in three major transmission lines crossing diverse physiographic conditions. This paper will refer only to two of the three projects covering a stretch of 610 km. In the course of the projects, the GIS and remote sensing technologies ILWIS and ARC/INFO GIS, Spot and Landsat Images were applied for route selection. The methodological sequence using GIS and satellite images are outlined in Fig. 2.

### Use of satellite images

Figures 3 and 4 show the LANDSAT images used for the route selections of the Paipa–Bucaramanga and San Carlos–San Marcos transmission lines. The image in Fig. 4, covering an area of 180×100 km shows the line corridor. The information source for this analysis include LANDSAT Image TM9-56 and TM9-57, basic cartography (1 cm:250 m), and participating environmental experts. This satellite image is taken by passive sensors which record the reflection of solar electromagnetic radiation on the earth's objects through the combination of the seven bands used in the division of the electromagnetic spectrum. This process allows the identification of vegetation cover, water bodies, geological formations, urban areas, major facilities, and other characteristics.

Seven-step processing and analysis procedure was conducted on the LANDSAT images, namely:

(1) *Satellite image processing*: the satellite image is prepared for specific interpretation (e.g. geology, landuse);

(2) *Georeferencing*: using the digitized base map, the satellite images were placed in geographical coordinates;

(3) *Preparation of images in false color for texture analysis*: This allows representation, through colors, of the different textures identifiable in the images reflecting vegetation, water, landforms, infrastructures etc.;

(4) *Preparation of images for physical processes analysis*: Geomorphologic processes, soil conditions, faults, etc. are determined in 1 cm:1 km scale which eventually serves as primary data to carry in the field for verification and more detailed investigation;

(5) *Principal components analysis*: Composite landscape units are created by combining components (e.g. textures and landform) to aid in image interpretation;

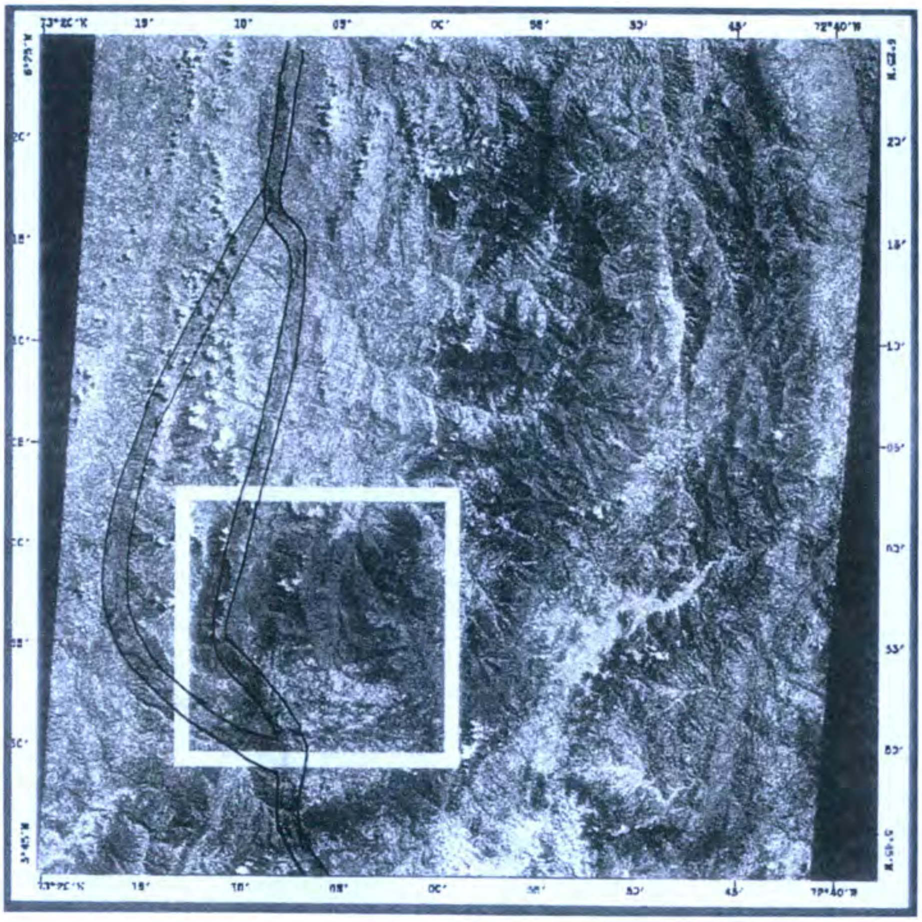


Fig. 3. "Virolin" window of LANDSAT satellites image. Paipa–Bucaramanga line. The image shows a highly sensitive and critical area, Virolin Natural Reserve, which is framed with a window in a Landsat image of the Paipa–Bucaramanga 230 kV transmission line. This image was used in the Environmental Analysis of Alternatives. Two alternative corridors are at the left of the Virolin Reserve.

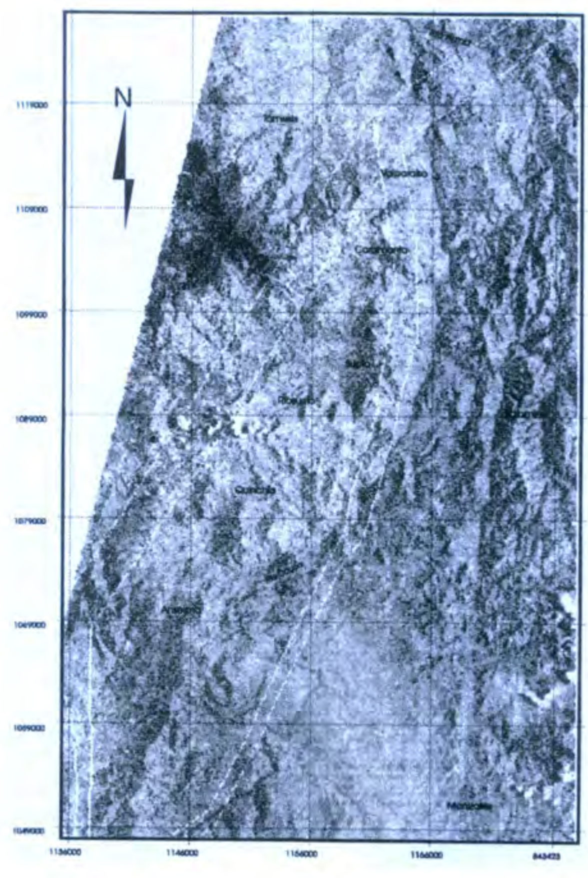



Fig. 4 (*opposite*). San Carlos–San Marcos 500 kV transmission line. Black and white reproduction of color composition LANDSAT TM satellites image. The image covers an area of 180×180 km in the middle section of the San Carlos–San Marcos 500 kV transmission line with a 380 km total length. In this section there were two corridors alternatives analyzed in the Route Selection Study of the design's process.

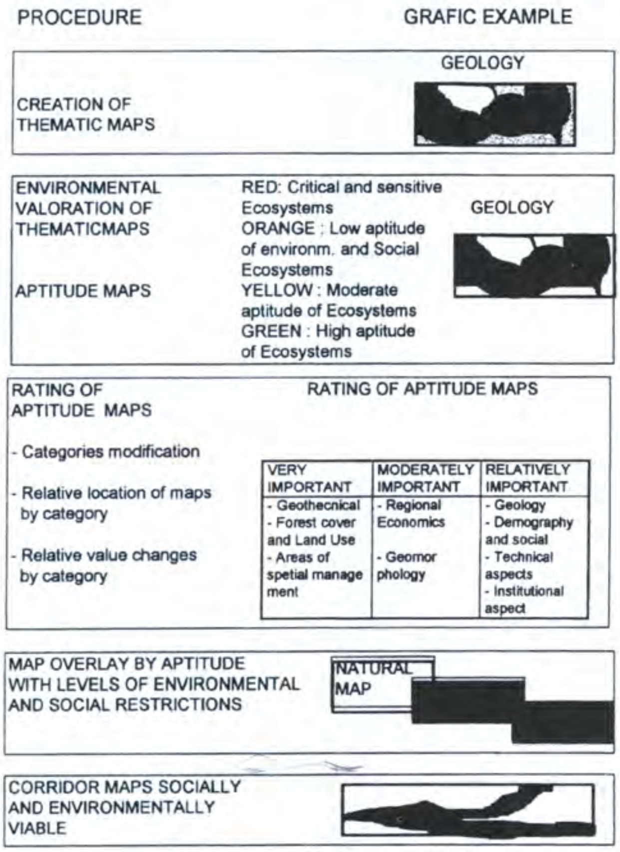



Fig. 5. SIG implementation of environmental selection of route.

(6) *Automatic classification*: Allows identification at a greater level of detail (1 cm:500 m) significant features such as vegetative cover and landuse; and

(7) *Topographic analysis and generation of digital terrain models*: Different digital models are generated by combining the satellite image with the topographic map in order to present features as drainage systems and existing roads.

## The use of GIS in route selection

The digital cartography prepared from information provided by environmental specialists was processed and analyzed through ILWIS and ARC/INFO. The general methodology for analyzing and processing information through ILWIS is summarized in Fig. 5 and through ARC/INFO is summarized in Fig. 6.

In order to spatially identify the environmentally sensitive areas, the corridor was divided into microareas (500×500 m). Each one of these areas was assigned an environmental indicator (relative weight) ranging from a zero sensitivity reading to extremely high sensitivity reading. The relative weights assigned to landscape units conform with the categories used in the Law No. 99 of 1993. Total environmental sensitivity ($S_t$) is a logical function of sensitivity for each one of the environmental components, and may be understood in the following equation:

$$S_t = f(E_t, E_r, P_c, D_p, C_u)$$

where $E_t$ is sensitivity due to geological stability, $E_r$ due to erosion, $P_c$ due to proximity to water bodies, $D_p$ due to biological diversity or agricultural productivity and $C_u$ due to compatibility with land use. The interpretation of satellite images and its conversion to cartographic-type maps was made with the ERDAS Imagine System developed by ERDAS Inc. on a Silicon Graphics workstation.

## The use of GIS for environmental impact assessment and monitoring

Environmental impact assessment is defined as a process which attempts to identify, predict and assess the likely consequences of proposed development activities. The GIS has broad utility in the analytical and integrative phases of environmental impact assessment because it facilitates simultaneous and collaborative study be-

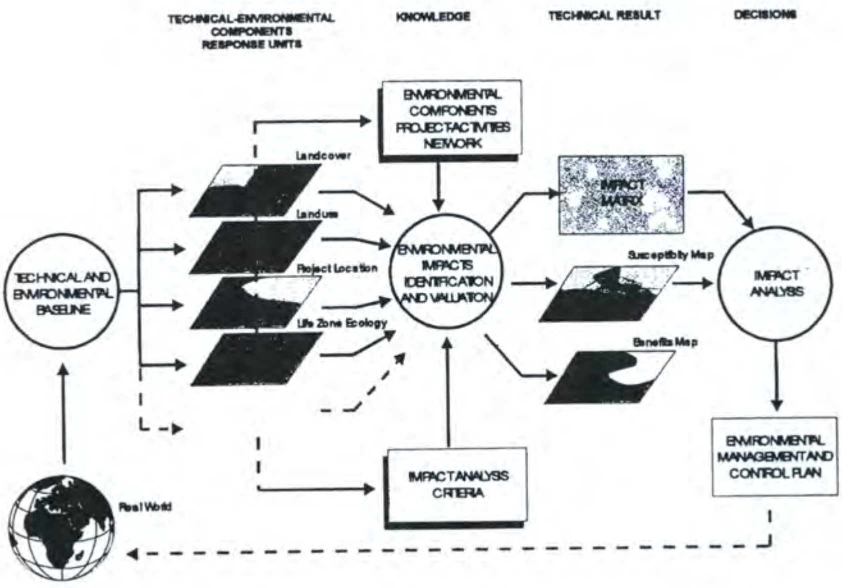



Fig. 6. Conceptual model for environmental impact analysis.

tween engineers and environmental experts as well as the visualization of environmental components and impacts. The GIS is an effective technique in identifying possible interrelationships and has potential for identifying geographic areas and environmental issues of particular concern while easily communicating the information in visual form to the public.

The GIS implemented for power transmission line design and for performing the environmental impact evaluation has a relational structure supported by ESRI's ARC/INFO system and uses ORACLE as the data base management system. This system was designed for a client/server environment so as to permit easy access of different specialists within the design and environmental studies group.

Environmental components for the evaluation of impacts are: geology, vegetation, soil and land use, fauna and flora, water sources, transportation access and socio-economic issues. The evaluation of impacts is performed with the methodologies of impact matrices and network by components and activities. Besides defining activities, potential impacts are categorized and evaluation criteria are defined for this systematic evaluation.

The Entity/Relation model, illustrated in Fig. 7, allows the adequate integration and management of information gathered for each environmental component in every microarea of the corridor of the project. Figure 7 shows, as example, the entity/relation model for the vegetation component.

To evaluate impacts, the variables defining the "impact panorama" or reference frame for the definition of impacts are determined for each environmental component. Thus, the following function is obtained:

$$C_i = F(V_1, V_2, V_3, \ldots, V_n)$$

where $C_i$ is a component, like vegetative cover, and the $V$'s are independent variables defining the impact on the component. For example, in the case of vegetative cover the independent variables are life zones, physiographic position and slope. Life zones are defined on the basis of altimetric levels, temperatures and rainfall curves. These variables are obtained by spatial interpolation of data collected from meteorological stations.

When the component activities of the project are identified, together with the possible impacts resulting from such activities and with the dependency variables for each environmental components, evaluation models of impacts are determined and discriminated by *activity/ category, environment/impact/criteria* on the *condition/ cause/symptom* relation. This systemic model diagnoses (measure of criteria) the symptom (impact) based on known causes (activity). Figure 6 illustrates a schematic description of the model.

## RESULTS AND DISCUSSION

ILWIS application (Integrated Land and Water Information System)
The ILWIS–GIS software package was applied in two corridor projects of ISA. Its most important contribution is manifested during the route selection phase of the projects. The ILWIS system facilitates comparative rating and evaluation of the corridor alternatives through statistical results produced by the system. The results of this application are based on pixel numbers which have been assigned numeric weights to spatially define the levels of area sensitivity within the corridors. In like manner, the general environmental management requirements are determined to identify the level of ease or difficulty in managing the corridors.

The categories applied in ILWIS are compatible with those stated in the Law No. 99 of 1993 and they are as follows:

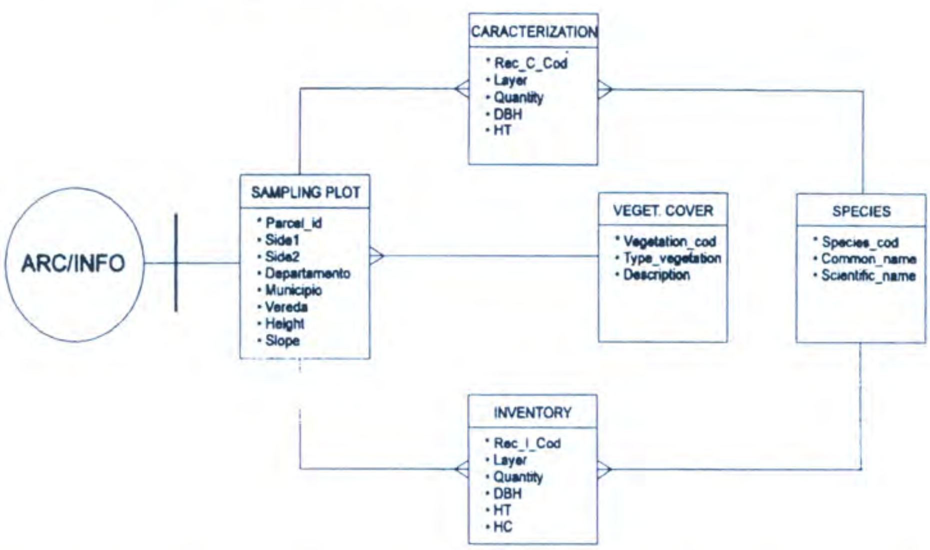



Fig. 7. Entity-relation diagram for forest inventory. San Carlos–San Marcos transmission line.

*Highly Sensitive and Critical Area.* These are ecosystems of immense ecological importance that are spatially delineated and completely avoided in the selection of the corridor.

*Low Ecological and/or Social Aptitude.* This constitutes ecosystems that may be considered in the selection of the corridor but are highly susceptible to ecological and social impacts imposed by the proposed transmission lines construction and operation. These areas are also those that are highly susceptible to technical, economic and construction difficulties.

*Moderate Ecological and/or Social Aptitude.* This constitutes ecosystems with similar conditions as in low aptitude that manifest moderate limitations.

*High Ecological and/or Social Aptitude.* This constitute ecosystems that may be assimilated within the corridor because only negligible impacts as well as the likelihood of occurring positive impacts are expected from these areas.

In Fig. 8, we see the distribution of environmentally sensitive areas in the Bucaramanga–Paipa corridors. Two corridor alternatives are presented, the eastern and the western corridors, both of which illustrate rather similar patterns in their levels of aptitude.

As illustrated in Fig. 8, the western corridor contains more critical areas, in terms of ecological importance, than the eastern corridor. The ecosystems found in the area which were categorized as significant are those found in extreme high altitudes such as the *paramos* or fragile mountain ecosystems and undisturbed tropical forest reserves. The areas that require special management, most of which are distributed in the southern section of the corridors, include lakes, forest covers, archaeological sites, utility lines and human settlements.

Toward the north end, a unique geological formation known as the Cañon of Chicamocha, poses tremendous challenge both for construction and environmental protection. The cañon is characterized by extremely steep slopes, unstable soils and the lack of access.

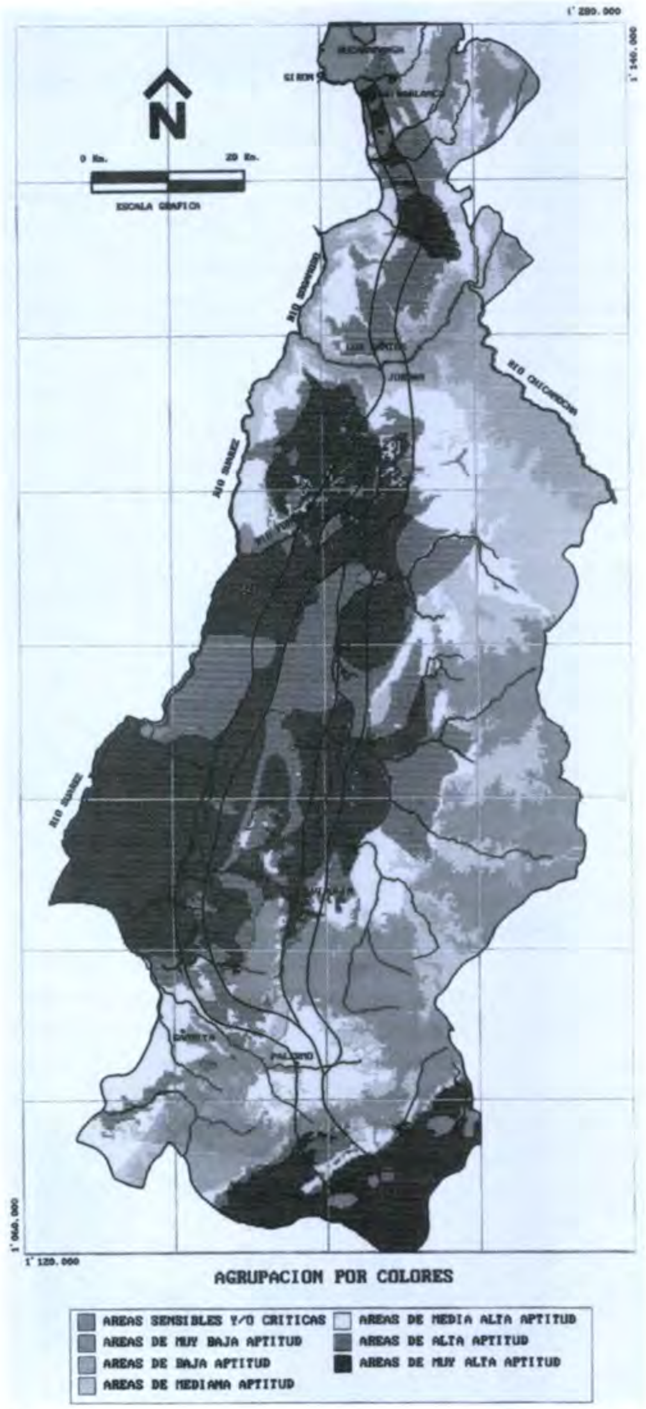



Fig. 8. Environmental sensitive areas in Bucaramanga–Paipa 230 kV line. Alternatives Environmental Analysis. This map was originally in color, but it is perfectly possible to see different types of greys corresponding to different environmental sensitivity and aptitude categories (7 in the map): highly sensitive and critical areas; very low aptitude; low aptitude; moderate aptitude; moderate to high aptitude; high aptitude; and very high aptitude.

## ERDAS application

Figure 9 illustrates the results of the sensitivity analysis in the corridors. The information source for this analysis include LANDSAT Image TM9-56 and TM9-57, basic cartography (1 cm:250 m), and participating environmental experts. Information processing was achieved using ERDAS IMAGINE 8.1. As illustrated in Fig. 9, the corridor and its alternative segment is generally characterized by low to moderately high sensitive areas. Areas with extremely high sensitivity have been avoided during preselection using the ILWIS package. The information provided in this map facilitated planning of the environmental impact study. The subsequent implementation of the impact evaluation was focused in areas of higher sensitivity.

Figure 10 shows a comparison of two route alternatives from a viewpoint of environmental sensitivity (Torres 1994). The fundamental contribution of ERDAS was to provide information on the status of the environmental components over the extremely large area covered by the project. This information was used to

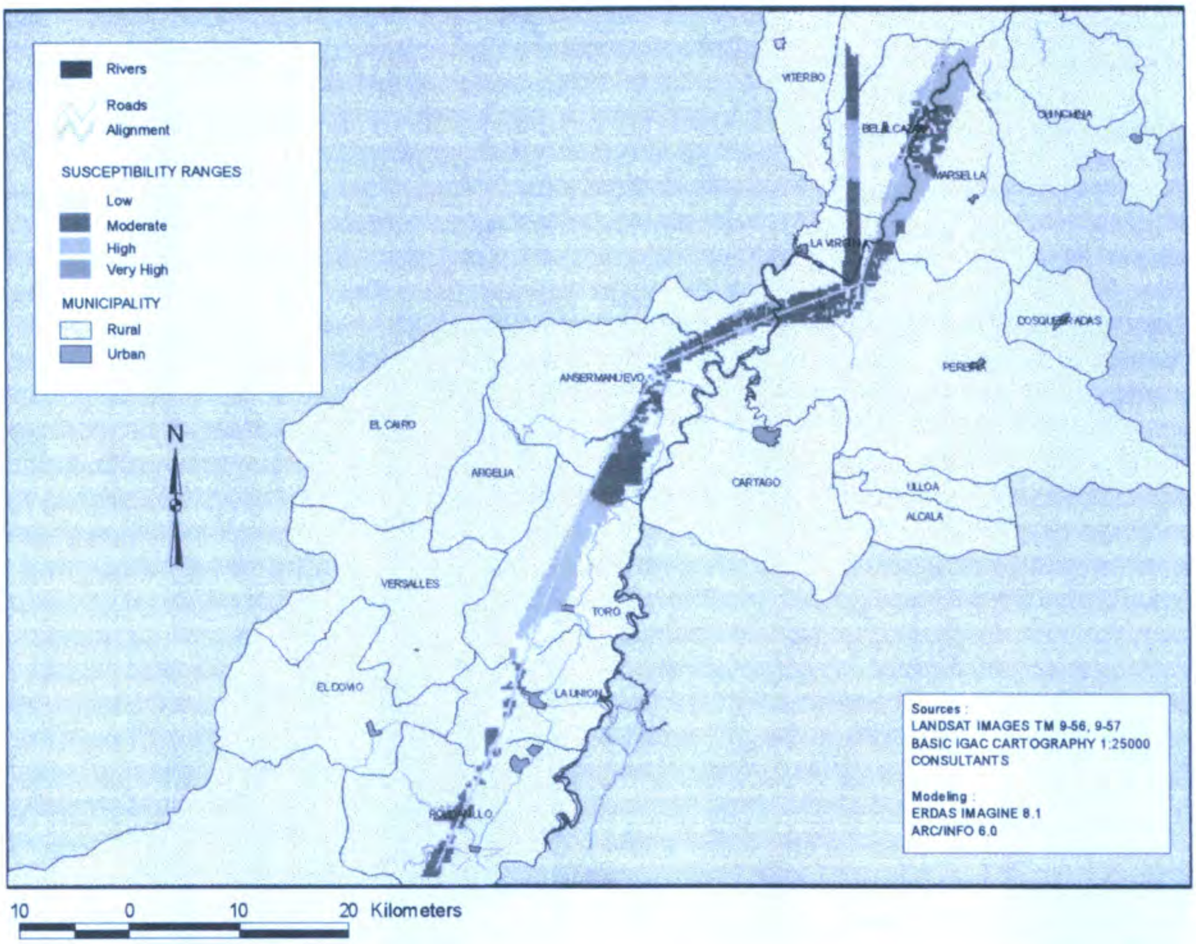



Fig. 9. Environmental susceptibility in the San Carlos–San Marcos 500 kV transmission line.

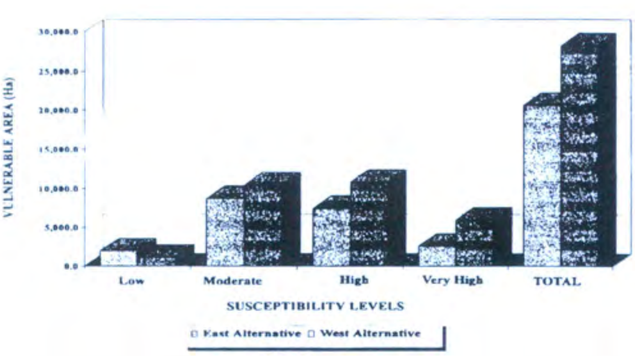



Fig. 10. Comparison analysis of route alternatives in the San Carlos–San Marcos transmission line.

examine the sensitivity levels of the two preselected corridors and determine which of the two are less sensitive from an environmental perspective.

## ARC/INFO application

The evaluation of environmental impacts can be difficult because it is necessary to see all the possible actions that a proposed project may pose to the environment. It is also difficult to deal with a situation, such as envisioning impacts of a proposed project, that involves a lot of uncertainty. The application of ARC/INFO, as illustrated earlier in Fig. 6, attempts to resolve some of the difficulties in environmental assessment by promoting a more systems approach that focuses on causal chains that dynamically link potential causes and subsequent effects. A systems approach not only helps in a comprehensive understanding of the impacts but in achieving the integration of impacts with other impacts that must be considered by decision makers.

The application of GIS for environmental impact analysis emphasizes the importance of correlating impacts of the many phases of construction activities to different environmental components and sensitive areas throughout the 380 km route of the San Carlos-San Marcos Line. To consider such a huge number of variables it was necessary to automate the impact evaluation to support the decision-making process of the environmental and engineering design groups. The importance of GIS is the move toward more precision in impact evaluation and improved criteria allowing the evaluation of impacts based on the dynamics of the environment, that is on the flow of materials and goods within and among affected resources (Erickson 1993.)

## CONCLUSION

Geographic Information Systems (GIS) and remote sensing (RS) technologies were successfully applied in the route selection and environmental evaluation of two high voltage transmission lines with a length of approximately 610 km, the first applications ever made in Colombia. They facilitate the evaluation of rights-of-way in a manner that is easy and reliable and allow the execution of a dynamic and systematic model which optimizes parallel engineering and environmental evaluation processes. This feature of the GIS and RS is significant given the spatial magnitude of transmission line projects and requirements in rights-of-way management.

GIS and RS addresses the need for more accurate methodologies in environmental design and research through a system which allows the objective and automatic realization of environmental sensitivity and impact studies. The applications minimize subjectivity which may arise due to the extension of analysis in different situations over a period of time. GIS and RS not only provide high-quality results but their application also permit the reduction of design time and costs and promote the implementation of concurrent engineering as early the conceptual design stage.

## REFERENCES

Bell, T. 1995. Remote sensing — spatial report. IEEE Spectrum, March 1996.

Erickson, P. 1994. A Practical Guide to Environmental Impact Assessment. Academic Press. San Diego, California.

ESRI (Environmental Systems Research Institute Inc.) 1994. Understanding GIS — The ARC/INFO Method.

Interconexion Electrica S.A. and Consultoria Colombiana S.A. 1995. Route selection and transmission line design San Carlos–San Marcos — Final Report. Bogotá, Colombia.

Salgado, M. 1995. Route selection of Paipa–Bucaramanga and Ocaña–El Copey Transmission Lines. Final Report. Bogotá, Colombia.

Torres, A., G. Guevara, B. Calinao, M. Nuñez, F. Anzola, and N. Orozco. 1994. Integration of environmental component to engineering in the selection of route alternatives for a transmission lines. ACIEM XI Power Journal, June.

## *BIOGRAPHICAL SKETCHES*

***Luis Fernando Cadena***

*ISA, Calle 12 Sur No. 18-168, Medellin, Colombia*

Geographic Engineer and Coordinator of Environmental Studies for Interconexion Electrica, S.A. ISA, Medellin, Colombia. Mr. Cadena initiated the use of RS and GIS technology in ISA.

***Bernardita Calinao***

*21 Old Farms Lane, Cazenovia, NY 13035, USA*

Human Ecologist from the University of the Philippines. She has an MS and Ph.D. degree in Environmental Science from the State University of New York, Syracuse. She is a partner and international consultant of Tecnologia Ambiental S.A., Bogotá, Colombia

***Alvaro Torres***

*Consultoría Colombiana S.A., Carrera 20, 37–28, Bogotá, Colombia*

Electrical Engineer from the Universidad Industrial de Santander, 1975. He has MS and Ph.D. degrees in Electrical, Computing and Systems Engineering from Rensselaer Polytechnic Institute, Troy, New York. He is currently the Technical Manager of Consultoría Colombiana S.A. and Professor of Electrical Engineering at Universidad de los Andes, Bogotá, Colombia

***Fernando Anzola***

*Consultoría Colombiana S.A., Carrera 20, 37–28, Bogotá, Colombia*

Cadastral Engineer and Geodesics from Universidad from the Distrital Francisco José de Caldas (1992). Consultoría Colombiana S.A. Bogotá, Colombia

# Part IX
# Wetlands

# 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

**Denis P. Blais and Daniel L. Simpson, Jr.**

A study to determine the effects of a buried gas pipeline on water quality, stream morphology and habitat, and biotic populations was performed on six cold water streams in upstate New York. The six streams represented three general morphological types based on gradient and bottom substrate composition (steep gradient/cobbles and gravel; steep gradient/sand and gravel; gentle gradient/sand and silt). Permanent transects were established upstream of the right-of-way, along the centerline of the pipe, and downstream of the right-of-way for each stream. Four water quality parameters, nine in-stream and stream side habitat variables, and biotic populations were assessed prior to, during, and for three years following construction of the pipeline. The results of the water quality measurements showed no apparent effect on water temperature, pH, or dissolved oxygen during and following construction of the pipeline. The primary impact to the streams was an increase in total suspended solids which occurred during construction activities. Total suspended solids measurements were highest along the centerline transect and decreased by 51% to 82% 100 m downstream. Generally, percent riffle fines, percent pools, the amount of instream cover, the amount of stream side vegetation, and percent mid-day shade all decreased within the right-of-way following construction, while the percentage of gravel and cobble increased. Overall, there appeared to be no long-term effects on benthic invertebrate populations for two of the streams included in the analysis, and fish populations appeared largely unaffected for all six streams.

*Keywords*: Pipeline, trenching, water quality, stream habitat, benthic invertebrates, fish populations

## INTRODUCTION

Previous research has demonstrated that potential impacts to streams resulting from buried pipeline construction and the long-term presence of a pipeline right-of-way include increased suspended sediments and bedload, altered riparian and in-stream habitat structure and composition, and changes in downstream water quality (Baddaloo 1978, Cordone et al. 1961, Gartman 1984, Tsui et al. 1981, Vinikour et al. 1987, Young et al. 1991, Zallen 1984). These impacts have the potential to affect populations of benthic organisms and fish that inhabit these systems.

The primary concerns regarding pipeline construction through streams pertain to increased turbidity levels and sedimentation. Previous studies have produced conflicting results regarding the effects of increased turbidity and sedimentation from pipeline construction on fish and benthic invertebrate populations. Cordone et al. (1961) reviewed studies that investigated biological effects of increased sedimentation and turbidity on aquatic systems and concluded that sedimentation can adversely affect productivity through all trophic levels. Vinikour et al. (1987) found that pipeline construction across the Little Miami River (a warm water fisheries) reduced fish and invertebrate populations within 100 m downstream for up to eight months as a result of increased sediment loads. These populations subsequently returned to approximate, pre-construction estimates. Other studies have indicated only minor, short-term decreases in benthic invertebrate populations, wherein the declines were limited to the season during which construction was completed (Baddaloo 1978, Tsui et al. 1981, Young et al. 1991). One study by Gartman (1984), in the right-of-way portion of a Pennsylvania study stream, found that benthic invertebrate populations actually increased as a result of heavy invertebrate colonization of the newly exposed substrate following construction.

Compared to studies of the effects of turbidity and sedimentation on benthic invertebrates, the effects of pipeline construction on fish populations and spawning are not as well documented. One study on mountain whitefish (*Prosopium williamsoni*) in British Columbia, demonstrated that no detrimental impacts to incubating eggs or juveniles occurred as a result of pipeline construction (Zallen 1984). The apparent lack of documentation of the effects of turbidity and sedimentation on fish populations is attributed primarily to strict regulatory restrictions prohibiting pipeline construction during sensitive fish spawning periods.

This study was prompted by the general lack of data concerning pipeline crossings of cold water streams in the northeastern United States, and because the majority of existing studies are unreplicated "one-stream" studies or focused primarily on the effects of pipeline construction on the physical attributes and water quality of streams, rather than biota. This study was designed for the Iroquois Gas Transmission System (IGTS) to evaluate upstream and downstream physical characteristics, habitat structure and composition, water quality, and fish and benthic invertebrate populations prior to and following construction of the pipeline. The specific objectives include: (1) to determine the effects of pipeline construction on water quality during the construction period; and (2) determine whether there are any long-term effects on stream water quality, habitat, or biotic populations resulting from pipeline construction and the introduction of a cleared right-of-way to the stream corridor.

## METHODOLOGY

Six cold water streams (three small stream systems and three large stream systems), all located in New York State (Fig. 1), were selected based on three criteria: (1) the proposed pipeline crossing technique; (2) stream bottom substrate type; and (3) stream flow rates (Table 1). The proposed pipeline crossing techniques included a wet ditching technique or a dry/partially dry ditching procedure depending on the situation. Stream morphological categories included a steep gradient with a rock/cobble/gravel bed; a steep gradient with a sand/gravel bed; and a gentle gradient with a sand/silt bed. All of the streams have been designated as trout supporting waters by the New York State Department of Environmental Conservation.

A total of five surveys were performed on each stream. Pre-construction surveys of each study site were conducted in June and July of 1991 prior to the initiation of in-stream construction activities. Construction surveys were conducted for each stream during August and October of 1991 (two surveys per stream), and subsequent surveys for each stream during November 1993, August and September 1994, and August 1995.

### Water quality and stream habitat

For each of the selected streams, four belt transects (approximately 5 m in width), were established perpendicular to stream flow at 50 m upstream of pipeline crossing, on the centerline of the pipe, 50 m downstream of the pipeline crossing, and 100 m downstream of the crossing. Measurements of water quality and habitat parameters, benthic invertebrate populations, and fish populations were obtained at each of the four belts.

Quantitative water quality and stream measurements included temperature, pH, minimum dissolved oxygen. Water samples were collected and sent to laboratories (Adirondack Environmental Services, Inc. during 1991–1994 and Upstate Laboratories, Inc. 1995) for analysis of total suspended solids. Visual observations were used to make qualitative assessments of habitat variables including riffle fines, percent pools, percent in-stream cover, percent streamside vegetation, and percent midday shade. The percent of the stream bottom of the various substrate types (boulder, cobble, gravel, sand, and silt) were also estimated for each of the four belt transects.

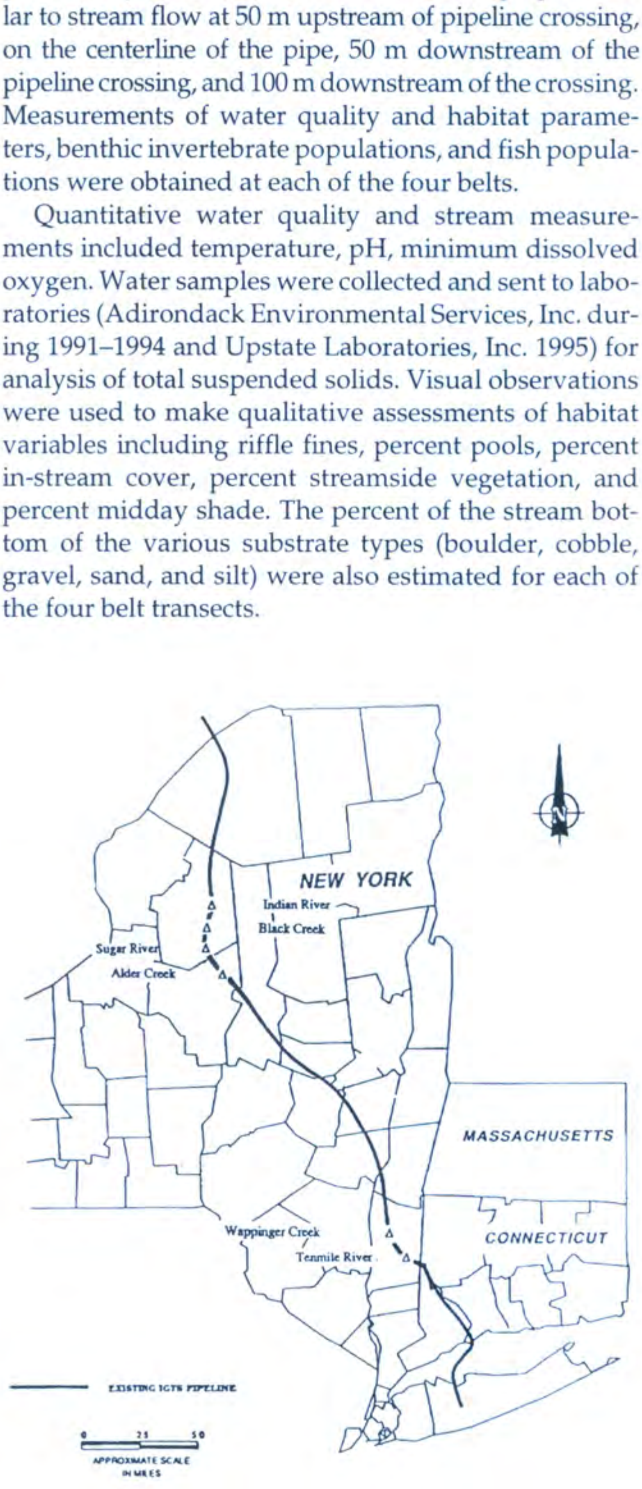



Fig. 1. Geographic location of the six cold water streams in New York State in relation to the Iroquois Gas Transmission System pipeline right-of-way.

**Table 1. Name, location, crossing technique, and morphological characteristics of the six study streams. NYSDEC uses an alphabetical system for the classification of waters on the basis of existing or expected best usage and range from Class A (the highest quality) to Class D (lower quality). A "(T)" designation following the water classification indicates that the aquatic system is capable of supporting trout populations.**

| Stream system | Location Town/county | Proposed crossing technique | Stream gradient/ bottom substrate | Approx. width (m) | Average depth (cm) | NYSDEC classification |
|---|---|---|---|---|---|---|
| Indian River | Diana/Lewis | wet ditching | steep/sand and gravel | 5 | 91 | C(T) |
| Black Creek | New Bremen/Lewis | wet ditching | gentle/sand and silt | 5 | 122 | C(T) |
| Sugar River | Leyden/Lewis | wet ditching | steep/rock, cobble, and gravel | 24 | 122 | C(T) |
| Alder Creek | Boonville/Oneida | wet ditching/dry or partially dry ditching | steep/sand and gravel | 5 | 122 | C(T) |
| Wappinger Creek | Pleasant Valley/ Dutchess | wet ditching | gentle/sand and silt | 17 | 122 | B(T) |
| Tenmile River | Dover/Dutchess | wet ditching | steep/rock, cobble, and gravel | 23 | 107 | C(T) |

Upstream and downstream measurements of the four water quality variables and six stream habitat parameters were recorded during active pipeline construction (e.g., trenching, back filling, bank restoration) on the Indian River, Black Creek, Sugar River, and Alder Creek. Pre-construction measurements of temperature, pH, and dissolved oxygen were not determined for Wappinger Creek and the Tenmile River due to landowner access restrictions outside of the right-of-way. Additionally, landowner restrictions during construction also prohibited data collection in the off right-of-way belt transects for Wappinger Creek, and consequently, these data were not included in the analysis for these two systems.

### Benthic invertebrates

Benthic invertebrates were collected from each of the four belt transects using a D-frame dip net Bottom substrate was kicked up and disturbed to dislodge invertebrates while the net was held immediately downstream to capture drifting invertebrates swept up in the current. Additionally, individual rocks also were lifted and examined and individual organisms were collected. All collected individuals were preserved in 100% isopropyl alcohol and identified to Order, and a calculation of species diversity was made using the Shannon–Wiener index of diversity (Ricklefs 1979). Pre- and post-construction benthic invertebrate data was available for only two of the streams; Wappinger Creek and the Tenmile River. Statistical analysis on diversity indices was performed using a Chi-square Goodness of Fit Test.

### Fish populations

Fish were sampled and collected at each of four transects using electroshocking gear. Each transect belt was systematically sampled and all stunned fish were netted, identified to species, tabulated, measured for total length to the nearest millimeter, and immediately released.

The United States Fish and Wildlife Service Habitat Suitability Index Model for brook trout (*Salvelinus fontinalis*) was used as the basis for the stream water quality and habitat parameter evaluations (Raleigh 1982). The model provides optimum ranges for a variety of stream habitat variables, as well as values which limit use by brook trout. Brook trout are widely distributed in New York in a variety of coldwater habitats and are generally a good indicator of the overall quality of cold water stream habitats. Values obtained for each water quality and habitat variable, for both pre- and post-construction data, were compared to the optimum range for brook trout as described in the Habitat Suitability Index Model. These measurements were analyzed to ascertain effects of the pipeline crossing. Tabulated data, for pre- and post construction, obtained from the fish population sampling were used to calculate species diversity using the Shannon-Wiener diversity index (Ricklefs 1979). A Chi-square Goodness of Fit Test was used to evaluate pre- and post-construction fish diversity data for each of the streams.

## RESULTS

### Water quality and stream habitat

The results of the water quality measurements taken during construction showed no apparent effect on water temperature, pH, or dissolved oxygen content for the Indian River, Black Creek, Sugar River, and Alder Creek. Total suspended solids increased within and downstream of the right-of-way, especially during trenching activities (Table 2). Total suspended solids

**Table 2. Water quality parameters and mean values for temperature (C), pH, minimum dissolved oxygen (MDO), and total suspended solids (TSS) for four study streams prior to, during, and after pipeline construction. Water quality parameter range values are provided only for those measurements taken during construction (1991). MDO values are not available for the surveys performed in 1995.**

| | Water quality parameter | Pre-construction (Jun–Jul 1991) | Construction (trenching) (Aug–Oct 1991) | Post-construction | | |
|---|---|---|---|---|---|---|
| | | | | Nov. 1993 | Aug–Sep 1994 | Aug 1995 |
| Indian River | Temp. (C) | 24.0 | 18.8 (18–19) | 3.0 | 16.0 | 20.0 |
| | pH | 6.4 | 6.2 (5.9–6.7) | 5.7 | 5.8 | 7.4 |
| | MDO (mg/l) | 8.2 | 5.9 (5.7–6.0) | 7.7 | 6.8 | – |
| | TSS (mg/l) | <1 | 442.6 (4.2–1420) | 1.0 | 3.9 | 4.2 |
| Black Creek | Temp. (C) | 20.0 | 15.5 (15–16) | 3.0 | 16.8 | 22.3 |
| | pH | 6.8 | 6.8 (6.6–7.3) | 6.9 | 6.8 | 8.6 |
| | MDO (mg/l) | 8.8 | 7.5 (5.3–9.6) | 9.9 | 8.2 | – |
| | TSS (mg/l) | 4.0 | 710.4 (7.4–1550) | <1 | 2.2 | 3.5 |
| Sugar River | Temp. (C) | 24.8 | 26.0 | 4.0 | 23.3 | 21.5 |
| | pH | 8.6 | 8.4 (8.3–8.7) | 9.2 | 8.2 | 8.4 |
| | MDO (mg/l) | 11.9 | 9.9 (9.4–10.4) | 11.9 | 8.3 | – |
| | TSS (mg/l) | <1 | 1413 (2.2–3780) | 1.9 | 17.3 | 2.5 |
| Alder Creek | Temp. (C) | 20.0 | 16.0 | 5.0 | 15.5 | 22.5 |
| | pH | 7.8 | 6.7 (6.6–6.8) | 7.8 | 7.5 | 8.2 |
| | MDO (mg/l) | 8.7 | 7 (6.9–7.1) | 8.9 | 8.1 | – |
| | TSS (mg/l) | 3.8 | 23100 (<1–11000) | 2.1 | 30.0 | 4.0 |

measurements for all streams ranged from 1,420 mg/l to 10,400 mg/l, and as high as 11,000 mg/l during the use of wet construction techniques on Alder Creek. The subsequent use of dry construction techniques on Alder Creek significantly reduced the amount of sediment loading to a level of 29 mg/l. Levels of suspended solids during construction activities in the four streams decreased rapidly downstream of the crossing. Total suspended solids measurements taken 100 m downstream during construction showed that suspended solid levels were reduced by 51% to 82% from levels measured at the right-of-way. There was no apparent long-term effect on water quality parameters resulting from pipeline construction in any of the streams surveyed. Water temperature, pH, dissolved oxygen, and total suspended solids measurements were similar in upstream and downstream transects for all post-construction sampling periods (Table 2). Water quality did vary from year to year resulting from annual climatic fluctuations however, no apparent fluctuations within any one year for upstream and downstream measurements were observed.

The primary change in bottom composition within the right-of-way as a result of pipeline construction was an increase in the percentage of gravel and cobble in the Indian River, Black Creek, Alder Creek, and to a lesser extent, Wappinger Creek. The percentage of riffle fines (substrate < 3 mm) decreased considerably in the right-of-way portion of these systems following construction. The percentage of fines in riffle areas within the right-of-way appeared unchanged by construction in the Sugar and Tenmile Rivers (Table 3).

In-stream cover (e.g., pools, rocks, debris, submerged vegetation) decreased as a result of construction within the right-of-way transect in all streams but the Sugar River (Table 3). By 1995, for Black Creek and Wappinger Creek, the percentage of in-stream cover and habitat had returned to approximate pre-construction estimations. Streamside vegetation and midday shade within the right-of-way transect of each study stream decreased dramatically as a result of the clearing of vegetation from the stream banks during pipeline construction.

### Benthic invertebrates

Eight orders of aquatic insects were identified from the six streams; all typical and including various species of mayfly, stonefly, caddisfly, and damselfly (Table 4). A comparison of benthic invertebrate diversity for two of the large stream systems with pre- and post-construction data (Wappinger Creek and the Tenmile River), showed no statistical difference in diversity values before and after construction of the pipeline ($X^2 = 0.29$, $p > 0.05$; and $X^2 = 0.42$, $p > 0.05$ respectively). As a result, there was no demonstrably negative effects on invertebrate populations resulting from pipeline construction on these two systems.

**Table 3. Physical and habitat characteristics along the pipeline right-of-way transect belt for six study streams. A total of seven in-stream and two stream side habitat variables were qualitatively assessed using visual observations during pre-construction surveys (1991) and for three years following construction (1993, 1994, and 1995).**

| Stream parameter | Indian River | | | | Black Creek | | | | Sugar River | | | | Alder Creek | | | | Wappinger Crk. | | | | Tenmile River | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 91 | 93 | 94 | 95 | 91 | 93 | 94 | 95 | 91 | 93 | 94 | 95 | 91 | 93 | 94 | 95 | 91 | 93 | 94 | 95 | 91 | 93 | 94 | 95 |
| Cobble (%) | – | 5 | 10 | 5 | – | 5 | 10 | 20 | 95 | 80 | 90 | 90 | 60 | 90 | 90 | 90 | 5 | – | 10 | 5 | 30 | 90 | 70 | 70 |
| Gravel (%) | – | 85 | 90 | 90 | – | 80 | 75 | 80 | 5 | 5 | 10 | – | – | 5 | 10 | 10 | 10 | 15 | 60 | 30 | 40 | 5 | 20 | 20 |
| Sand (%) | 90 | 10 | – | – | 40 | 10 | 10 | – | – | 10 | – | – | 30 | 5 | – | 5 | 70 | 35 | 10 | 5 | 20 | 5 | 5 | 10 |
| Silt (%) | 10 | – | – | 5 | 60 | 5 | 5 | – | – | 5 | – | 10 | 10 | – | – | – | 15 | 50 | 20 | 60 | 10 | – | 5 | – |
| Riffle fines (%) | 10 | 10 | <1 | 5 | 10 | 15 | 15 | 5 | 5 | 15 | 5 | 10 | 40 | 5 | 5 | 5 | 80 | 85 | 30 | 70 | 30 | 10 | 10 | 10 |
| Pools (%) | 50 | – | – | – | 40 | – | – | – | 20 | 10 | 10 | 10 | 65 | – | – | – | 90 | – | – | – | 40 | 20 | 5 | 10 |
| Instream cover (%) | 40 | – | 10 | 10 | 20 | 5 | 10 | 30 | 30 | 30 | 10 | 45 | 30 | 10 | 5 | 5 | 15 | 5 | 10 | 40 | 40 | 20 | 10 | 20 |
| Streamside veg. (%) | 10 | 65 | 70 | 70 | 90 | 10 | 10 | 10 | 90 | 40 | 40 | 30 | 90 | 10 | 10 | 10 | 70 | 10 | 10 | 10 | 95 | 10 | 20 | 30 |
| Midday shade (%) | 75 | <1 | 2 | <1 | 10 | 5 | 5 | – | 10 | 5 | 1 | 10 | 60 | 5 | 5 | 5 | 25 | 5 | 10 | 5 | 25 | 5 | 5 | 5 |

**Table 4. A comparison of benthic invertebrate data prior to and following pipeline construction for Wappinger Creek and Tenmile River. Total = the total number of organisms captured, and index = the calculated Shannon–Weiner diversity index value.**

| Benthic invertebrate order | Pre-construction | Post-construction | | |
|---|---|---|---|---|
| | (Jun–Jul 1991) | Nov 1993 | Aug–Sep 1994 | Aug 1995 |
| Wappinger Creek: | | | | |
| Emphemeroptera | 4 | 3 | 24 | 13 |
| Odonata | 1 | – | 4 | 7 |
| Plecoptera | 1 | 2 | 3 | 2 |
| Hemiptera | 2 | 1 | – | 1 |
| Megaloptera | 1 | – | 10 | 13 |
| Tricoptera | 1 | 4 | 46 | 14 |
| Coleoptera | 1 | 1 | 12 | 2 |
| Diptera | – | 1 | 2 | 7 |
| Total | 11 | 12 | 101 | 59 |
| Index | 5.93 | 5.21 | 4.44 | 5.99 |
| Tenmile River: | | | | |
| Emphemeroptera | 27 | 27 | 59 | 21 |
| Odonata | – | 1 | 1 | – |
| Plecoptera | 2 | 10 | 12 | 8 |
| Hemiptera | 1 | – | – | 1 |
| Megaloptera | 11 | 25 | 15 | 9 |
| Tricoptera | 6 | 10 | 12 | 20 |
| Coleoptera | 3 | 1 | 13 | 6 |
| Diptera | – | 3 | – | 5 |
| Total | 50 | 77 | 112 | 70 |
| Index | 3.63 | 4.62 | 3.97 | 5.42 |

## Fish populations

Twenty-seven species of fish were identified from the six streams for the years 1991, 1994, and 1995 (no data was collected for some streams in 1993 due to high water levels) (Table 5). Indian River, Black Creek, and Alder Creek are small, clear, cold water streams, and brook trout were collected from each for at least one sampling period. Forage fish consisted primarily of blacknose dace and creek chub. Sugar River, Wappinger Creek, and the Tenmile River are generally larger, cool-water systems. Small numbers of brook and brown trout were collected or observed within Tenmile River and Wappinger Creek; no salmonids were collected or observed from Sugar River and forage fish included: blacknose dace, creek chub, cutlips minnow, and common shiner. Some warm-water species, such

**Table 5. A comparison of fish population data prior to (1991) and following (1994 and 1995) construction for all six study streams. A total of 27 species of fish were documented over the course of the study. Total = the total number of fish captured per survey, and index = the calculated Shannon–Weiner diversity index.**

| Common name | Indian River | | | Black Creek | | | Sugar River | | | Alder Creek | | | Wappinger Crk. | | | Tenmile River | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1994 | 1995 | 1991 | 1994 | 1995 | 1991 | 1994 | 1995 | 1991 | 1994 | 1995 | 1991 | 1994 | 1995 | 1991 | 1994 | 1995 |
| American eel | – | – | – | – | – | – | – | – | – | – | – | – | – | 11 | – | – | – | |
| Brown trout | – | – | – | – | – | – | – | – | – | 3 | – | 1 | – | – | – | 1 | 1 | – |
| Brook trout | 1 | – | 13 | – | 1 | – | – | – | – | 1 | 25 | 2 | – | – | – | – | – | 1 |
| Grass pickerel | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – |
| Golden shiner | – | – | – | – | – | – | 12 | – | – | – | – | – | 34 | – | – | 52 | – | – |
| Cutlips minnow | – | – | – | 22 | 21 | 8 | 13 | 3 | 13 | – | – | – | 52 | 18 | 6 | 33 | 6 | 3 |
| Common shiner | – | – | – | 4 | 33 | – | 8 | 55 | – | – | – | – | – | 14 | – | – | – | 30 |
| Northern redbelly dace | – | – | – | – | – | – | 7 | – | – | – | – | – | – | – | – | – | – | – |
| Bluntnose minnow | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 9 |
| Blacknose dace | 7 | 19 | 18 | 7 | 39 | 36 | 40 | 14 | 60 | – | 9 | 2 | 11 | 1 | – | 10 | 11 | 44 |
| Longnose dace | – | – | – | 2 | 8 | 5 | 14 | 65 | 27 | – | – | – | – | – | – | 17 | 35 | 37 |
| Creek chub | 2 | 37 | 8 | – | 10 | 1 | 9 | 8 | 39 | – | – | 4 | 7 | 3 | 2 | – | 10 | 15 |
| White sucker | – | – | – | – | 15 | 11 | – | 8 | 12 | 2 | – | 4 | 56 | 20 | 8 | 34 | 44 | 20 |
| Yellow bullhead | – | – | – | – | – | – | – | – | – | – | – | 5 | 4 | 6 | – | – | – | – |
| Banded killifish | – | – | – | 1 | 4 | | – | – | – | – | – | – | – | – | – | – | – | – |
| Mottled sculpin | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – |
| Slimy sculpin | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – | – | – | – |
| Rock Bass | – | – | – | – | – | – | – | – | – | – | – | – | 35 | 40 | 17 | – | – | – |
| Redbreast sunfish | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – |
| Pumpkinseed | – | – | – | – | 2 | – | 5 | – | – | – | 1 | 13 | 15 | – | 2 | – | – | – |
| Bluegill | – | – | – | – | – | – | – | – | – | – | – | – | 2 | 10 | 4 | – | 1 | – |
| Longear sunfish | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – |
| Smallmouth bass | – | – | – | – | – | – | – | – | – | – | – | – | – | 10 | 7 | 20 | 45 | 27 |
| Largemouth bass | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – |
| White crappie | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 | – |
| Tessellated darter | – | – | – | – | 32 | 16 | – | 34 | 16 | – | 4 | – | 3 | 23 | 9 | 24 | 41 | 77 |
| Logperch | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Total | 10 | 56 | 39 | 37 | 26 | 77 | 10 | 32 | 16 | 6 | 41 | 32 | 21 | 14 | 58 | 19 | 29 | 45 |
| Diversity | 2.2 | 1.9 | 1.9 | 3.4 | 4.8 | 5.0 | 6.3 | 3.3 | 6.0 | 2.8 | 3.0 | 5.7 | 6.6 | 7.8 | 7.7 | 6.4 | 5.9 | 5.4 |

as pumpkinseed and bluegill sunfish, yellow bullhead and white sucker, were also collected. Although species diversity varied between years for all of the study streams, the diversity index values before and after construction were not significantly different from expected values ($X^2 = 0.04, p > 0.05$; $X^2 = 0.34, p > 0.05$; $X^2 = 1.03, p > 0.05$; $X^2 = 1.39, p > 0.05$; $X^2 = 0.13, p > 0.05$; and $X^2 = 0.09, p > 0.05$ for the Indian River, Black Creek, Sugar River, Alder Creek, Wappinger Creek, and the Tenmile River respectively). Species diversity actually increased in three of the study streams. As a result, there appeared to be no associated detrimental (i.e., decrease in species diversity) impact of pipeline construction on the fish populations located within these systems.

## DISCUSSION

### Water quality and stream habitat

The results of water quality measurements taken during construction show no apparent effect on temperature, pH, or dissolved oxygen. It was expected that dissolved oxygen would decrease as suspended solids increased during construction activities. However, there is no consistent pattern in the data to support this. In some cases, dissolved oxygen levels decreased slightly during periods of high siltation (i.e., during trenching, backfilling, and bank restoration); however, in most instances dissolved oxygen levels were unaffected or increased slightly. Consequently, there is no apparent correlation between construction activities and the level of suspended solids with decreased downstream dissolved oxygen levels. This may be due to the low amount of organic material found in the bottoms of the streams surveyed.

The most significant impact of construction activities was an increase in total suspended solids within and downstream of the right-of-way. Trenching resulted in the greatest levels of suspended solids. Increased suspended solids levels were generally of short duration, occurring only while in-stream work was being performed over a period of 1–3 days, so were likely not a limiting factor in biotic populations. There was no evidence of any fish kills occurring as a result of construction activities in any of the study streams.

Suspended solids during wet trenching of Alder Creek were far higher than in any of the other streams surveyed. This is largely due to the methods in which trenching was performed and the type of material (fine clays) being excavated from the trench. When Alder Creek trenching was completed using dry construction techniques there were far less sediments released to the stream showing the value of using dry construction techniques where possible. Previous studies have also documented that dry crossing techniques result in far less downstream turbidity and sedimentation, and result in little or no biotic impacts (Baddaloo 1978, Crabtree et al. 1978, Vinikour et al. 1987).

Increased suspended solids levels measured at the right-of-way during construction dropped in the streams surveyed by 51% to 82% within 100 m downstream of the right-of-way; however, it was not possible to determine the distance required for suspended solids to return to background, pre-construction measurements (due to constraints on access further downstream). This is consistent with previous studies which have shown suspended solids levels to remain above background as far as 400 m downstream of trenching activities (Vinikour et al. 1987).

There was no apparent long-term effect on water quality parameters (temperature, pH, dissolved oxygen, and total suspended solids) resulting from pipeline construction in any of the streams surveyed. No increase in water temperature was apparent downstream of the right-of-way, as was predicted would occur as a result of clearing of bank vegetation and reduced shading in the right-of-way. The values obtained for these water quality variables in all years were within the range of values described in the Habitat Suitability Index Model for brook trout as being capable of supporting a brook trout population.

There was considerable variation in other stream habitat parameters between transects and years, primarily as a result of natural stream variations and evolution processes. Natural stream evolution processes involve the movement of rock and fines along the stream course as banks are eroded and the bottom scoured during periods of high flows. The movement of boulders five feet in diameter along the stream courses of Sugar River and Tenmile River were evident over the course of the study. These natural processes worked to minimize the impacts of pipeline construction. There was no evidence in downstream transects of any stream in the years following construction that indicated continued sedimentation resulting from pipeline installation. High springtime flows appeared to have been sufficient to remove fines deposited downstream of the pipeline crossings. Previous studies have also found that spring flows are sufficient to remove accumulated sediments resulting from pipeline construction (Baddaloo 1978, Tsui et al. 1981, Gartman 1984, Young et al. 1991).

The primary change in bottom composition within the right-of-way as a result of pipeline construction was an increase in the percentage of gravel and cobble in Indian River, Black Creek, Alder Creek, and to a lesser extent Wappinger Creek. This is likely a result of the construction techniques of placing gravel over the trench and rock riprap on the banks, some of which may have fallen or eroded into the stream channel. No gravel was installed in Sugar River or Tenmile River due to high flow rates, and there was considerable amounts of rock already present in these rivers prior to construction. Consequently, these two rivers did not reflect the trend of increased amounts of gravel and cobble within the right-of-way transect following construction.

The Habitat Suitably Index Model for brook trout indicates that this increase in gravel and cobble within the right-of-way is beneficial. The model shows the optimal percentage of substrate materials of size class 10–40 cm (cobble) is greater than 8%. Large percentages of cobble and gravel are also beneficial for food production, as they provide anchoring sites and shelter for aquatic invertebrates. In addition, substrate materials of 2–7 cm are optimal for spawning areas, and the gravel placed over the trench in these streams is largely of this size. Consequently, although pipeline construction resulted in changes in bottom composition within the right-of-way, this alteration is largely beneficial.

The percentage of fines in riffle areas decreased in the right-of-way following construction in Indian River, Black Creek, and Alder Creek. This is largely due to the placement of gravel over the trench in these streams, and to a lesser extent, natural stream processes (e.g., flooding events). The percentage of fines in riffle areas within the right-of-way was largely unaffected by construction in Sugar River, Wappinger Creek, and Tenmile River. The Habitat Suitably Index Model for brook trout shows that habitat suitability increased as the percentage of fines in riffle areas decreased. Consequently, the decrease in fines within the right-of-way in Indian River, Black Creek, and Alder Creek as a result of pipeline construction is likely beneficial.

The percentage of pools within the right-of-way transect decreased consistently in all streams following construction. Pools were virtually eliminated from the right-of-way transect due to the construction practice of generally restoring a level bed to the stream following backfilling. The Habitat Suitably Index Model for brook trout shows the optimum percentage of pools between 30% and 70%, however a lack of pools is not considered sufficient to prohibit populations of brook trout. In addition, there are abundant pools upstream and downstream in close proximity (within 100 m) to the right-of-way in the streams surveyed. Consequently, although the decrease in pools within the right-of-way resulting from pipeline construction represents a detrimental impact to the habitat, it is not likely a limiting factor in local brook trout populations.

The percentage of in-stream cover decreased as a result of construction within the right-of-way transect in all streams except Sugar River. This decrease was no longer apparent in Black Creek and Wappinger Creek by 1995, indicating the beginnings of a recovery of the stream habitat. The Habitat Suitably Index Model for brook trout shows optimum habitat has greater than 10% in-stream cover. Although levels of in-stream cover in the right-of-way transect temporarily dropped below 10% following construction in some cases, by 1995 only Alder Creek had less than 10% in-stream cover (5%) within the right-of-way. Even in the case of Alder Creek, the lower levels of cover available following construction are not considered in the model as being sufficient to prohibit brook trout populations.

The amount of streamside vegetation and midday shade within the right-of-way transect of each study stream decreased as a result of pipeline construction. This is a result of the clearing of bank vegetation in preparation for construction activities. Although these effects were lessened somewhat by 1995, there had not been sufficient time for the streamside vegetation to return to pre-construction levels. (Federal regulations for pipeline operation require that a 3-m (10-ft)-wide riparian strip be allowed to revegetate in a natural state adjacent to stream banks.)

The Habitat Suitably Index Model for brook trout shows optimum habitat has greater than 50% streamside vegetation and between 50% and 75% midday shade. The right-of-way transects had not returned to these levels by 1995, and consequently this represents a potential, detrimental impact to the stream habitat. However, bank vegetation and shading will be restored naturally over time, aided by extensive landscape plantings installed by Iroquois, so this does not represent a permanent impact.

### Benthic invertebrates

As found in previous studies of the effects of pipeline construction (Baddaloo 1978, Tsui et al. 1981, Gartman 1984, Vinikour et al. 1987, Young et al. 1991), there were no demonstrable long-term effects on the invertebrate populations within Wappinger Creek and the Tenmile River resulting from construction of the pipeline. Differences among transects within individual streams are likely due more to natural differences in bottom type, flow rates, and other factors which influence invertebrate populations than pipeline construction, because there is no consistent pattern of downstream transects having suppressed invertebrate populations.

Comparisons of the overall diversity index of individuals collected over the duration of the study did not indicate a significant change. If benthic invertebrates downstream of the pipeline were being adversely affected by construction or the continued presence of the right-of-way, it would be expected that population variables would show a consistent declining pattern. Conversely, if invertebrate populations had been severely impacted by construction and were in the process of recovery, or were being positively affected by the presence of the right-of-way, population variables would tend to show an increase over the years. However, no patterns of either type were consistently shown in either stream. Consequently, variations in benthic invertebrate populations was likely due more to seasonal and localized in-stream fluctuations in habitat variables than a result of pipeline construction.

### Fish populations

In terms of the Shannon Weiner diversity index, the overall fish populations for all six streams were not significantly affected by pipeline construction. There were annual fluctuations in collection numbers and the calculated indices, however these were not statistically significant, and as a result indicate that no long-term, detrimental impacts to fish populations occurred.

Decreasing numbers of fish collected from Wappinger Creek in the years following construction may be indicative of an alteration to the stream habitat in the vicinity of the right-of-way which is resulting in lower local population levels. However, this cannot be verified with the data collected as part of this study. Stream conditions in the vicinity of the right-of-way may be causing fish to utilize other parts of the stream, or may otherwise be suppressing local populations. There were no results in the water quality and habitat surveys or benthic invertebrate collections performed in Wappinger Creek which would indicate any potential causes for lower populations in the vicinity of the right-of-way.

No consistent patterns of increasing or decreasing population health were apparent among the other streams over the duration of the study. Previous studies have also found no, or only short-term, impacts to fish populations resulting from pipeline construction (Zallen 1984, Vinikour et al. 1987).

Peterson (1993) found that fish use of 10–15-year-old electric transmission line rights-of-way was greater than adjacent undisturbed areas. This was attributed primarily to the presence of more numerous and deeper pools within the rights-of-way, and a greater concentration of overhanging shrubs facilitating larger numbers of terrestrial insects falling into the streams. There was evidence of increased fish populations in several of the study streams, however controlled population surveys were not performed so this cannot be verified. There also was not a consistent pattern of evidence of increased populations across all streams in the study.

The stream bottom morphologies along the right-of-way is generally more shallow, rather than deeper as in the Peterson (1993) study, and the bank vegetation had not reestablished sufficiently to provide significant inputs of terrestrial insects. Differences in construction methods may also have contributed to differences between this study and the Peterson (1993) study, which focused on electric transmission line rights-of-way. Streams are not excavated as part of electric transmission line construction, and are typically forded rather than bridged as with pipelines. Fording of streams may have resulted in the presence of deeper pools on the rights-of-way studied by Peterson. Consequently, the results of the Peterson study showing greater fish use of transmission line rights-of-way were not verified by this study of a pipeline right-of-way.

## ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciation to Louise Mango, Kevin Dominske, Craig Ferris, Dan Simpson, and Rod Soper for all of their invaluable help and support throughout the field season(s) as well as during the preparation of this manuscript.

## REFERENCES

Baddaloo, E.G. 1978. An assessment of effects of pipeline activity in streams in the Durham and Northumberland Counties of Ontario. Journal of the Canadian Society of Petroleum Geologists, 4(2).

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.

Crabtree, A.F., C.E. Bassett, and L.E. Fisher. 1978. The impacts of pipeline construction on stream and wetland environments. Michigan Public Service Commission, Lansing, Michigan.

Gartman, D.K. 1984. The impact of a pipeline crossing on the benthos of a Pennsylvania trout stream. Proceedings of the Third Symposium on Environmental Concerns in Rights-of-way Management, San Diego, California.

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.

Raleigh, R.F. 1982. Habitat suitability index models: brook trout. United States Department of Interior, Fish and Wildlife Service FWS/OBS-82/10.24. 42 pp.

Ricklefs, R.E. 1979. Ecology (2nd edn.). Chiron Press, Inc., Fitchburg, Massachusetts, pp. 685–687.

Schubert, J.P. and W.S. Vinikour. 1987. Effects on suspended and substrate sediments in two streams resulting from different gas-pipeline installation techniques. Fourth Symposium on Environmental Concerns in Rights-of-way Management, Indianapolis, Indiana.

Tsui, T.P.T. and P.J. McCart. 1981. Effects of stream-crossing by a pipeline on the benthic macroinvertebrate communities of a small mountain stream. Hydrobiologia, 79: 271–276.

Vinikour, W.S., J.P. Schubert, and D.K. Gartman. 1987. Comparison of impacts on macroinvertebrates and fish from gas pipeline installation by wet-ditching and plowing. Fourth Symposium on Environmental Concerns in Rights-of-way Management, Indianapolis, Indiana.

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 wiiliamsoni* Girard) in the Moyie River, British Columbia. Proceedings of the Third Symposium on Environmental Concerns in Rights-of-way Management, San Diego, California. pp. 488–498.

## *BIOGRAPHICAL SKETCHES*

***Denis P. Blais***

*Phenix Environmental, Inc., 30 Broadway, Suite 207, Kingston, NY 12401, USA*

Mr. Denis Blais has been working for Phenix Environmental, Inc. since 1995. He has a B.S. in biology from St. Lawrence University and has recently acquire a M.A. degree, also in biology, from the State University of New York at Binghamton. At Binghamton, he performed a radio telemetric study on the eastern hellbender, the largest aquatic salamander in North America. Mr. Blais is an avid fly fisherman and enjoys many of New York's trout streams.

***Daniel L. Simpson, Jr.***

*Phenix Environmental, Inc., 30 Broadway, Suite 207, Kingston, NY 12401, USA*

Mr. Dan Simpson, Jr. is an Environmental Scientist with Phenix Environmental, Inc. A graduate from the State University of New York College of Environmental Science and Forestry, he specializes in the performance of aquatic and terrestrial studies.

# Evaluating Transmission Line Clearing Methods for Minimizing Changes in Wetland Function

Julia W. Gaskin and Wade L. Nutter

Little information is available on the changes in wetland function due to transmission line clearing and construction. This type of information is critical to document minimal effects as may be required for laws regulating jurisdictional wetlands in the United States. The newly developed functional assessment methodology (the Hydrogeomorphic Approach or HGM) was used to evaluate and compare changes in wetland function in mineral flat wetlands in southeast Georgia due to various mechanized land clearing techniques. Functional assessments were conducted on wetlands before a proposed Right-of-Way (ROW) was cleared or at least 30 m off the existing ROW to provide reference data. Functional assessments were conducted in five mineral flat wetlands that were cleared by different mechanized techniques including clearing and grubbing of stumps by track crawlers, feller-buncher clearing and removal of trees with skidders (no stumps grubbed), and clearing and tree removal with low ground pressure (LGP) track crawlers. The HGM assessment indicated clearing the ROW by track crawlers and grubbing stumps created the greatest changes to wetland function. The least change in function was predicted for the wetland cleared with LGP track crawlers when the water table was at least 70 cm below the surface. The results of the HGM assessment suggests mineral flat wetlands in southeast Georgia can be cleared with minimal effects using LGP equipment under dry conditions; consequently, mitigation under Nationwide Permit 12 or an Individual 404 Permit should not be required.

*Keywords*: Jurisdictional wetlands, wetland function, hydrogeomorphic approach, transmission line construction, minimal effects

## INTRODUCTION

Section 404 of the Clean Water Act extends protection to many of the wetlands of the United States and acknowledges the benefits of functions that wetlands perform. Since 1990, permitting and mitigation have focused on impacts to wetland function based on the Memorandum of Agreement between the Corps of Engineers (COE) and the Environmental Protection Agency (EPA). Wetland "function" is defined as "the biological, physical or chemical processes that occur without regard to their importance or "value" to humans" (Taylor et al. 1990).

The COE has been developing a new approach to evaluate changes in wetland function — the Hydrogeomorphic Approach to Functional Assessment (Brinson 1993, Brinson et al. 1995). This approach classifies wetlands by geomorphic setting, dominant water source, and primary hydrodynamics. The Hydrogeomorphic Approach (HGM) uses data from "reference" wetlands within a wetland class to determine change in function.

Little information is available on the changes in function due to transmission line clearing and construction. This type of information is critical to document minimal effects and develop techniques that minimize functional change. The recent (December 1996) reissue of Nationwide Permit 12 (NWP 12 — Utility Line Backfill and Bedding), clarified that mechanized land clearing is authorized for both underground and overhead utility lines; however, use of this permit in forested wetlands requires Pre-Construction Notification. The nationwide permit system is designed to permit "minimal effects". Whether mechanized land clearing in Rights-of-Way (ROWs) is considered a "minimal effect" may depend on the width and length of the ROW, as well as the number and type of forested, jurisdictional wetlands the project crosses. If the COE does not expect the impact of mechanized land clearing in a project to be minimal, they may require mitigation as part of the NWP 12 or an Individual 404 Permit. The cost of obtaining an Individual 404 Permit or mitigating on a unit area basis for jurisdictional wetlands can be substantial. Mitigation banks in the southeastern United States charge $25,000 and upwards per hectare.

The southeastern Coastal Plain of Georgia has numerous pine flatwoods, many of which are jurisdictional wetlands. These wetlands are classified as mineral flats by HGM. Wetlands in the mineral flat class typically have large fluctuations in the water table (Brinson 1993, Rheinhardt et al. 1995). Mineral flat wetlands that are saturated or inundated in the winter to early spring usually have water tables at depths of 60 cm or greater below the soil surface during the late spring through fall (Comerford et al. 1996, Gaskin and Nutter, in press).

Due to the water table fluctuations, mineral flat wetlands may be able to be mechanically cleared with minimal effects. As a part of a larger project, this study used HGM to evaluate and compare changes in wetland function due to various mechanized land clearing

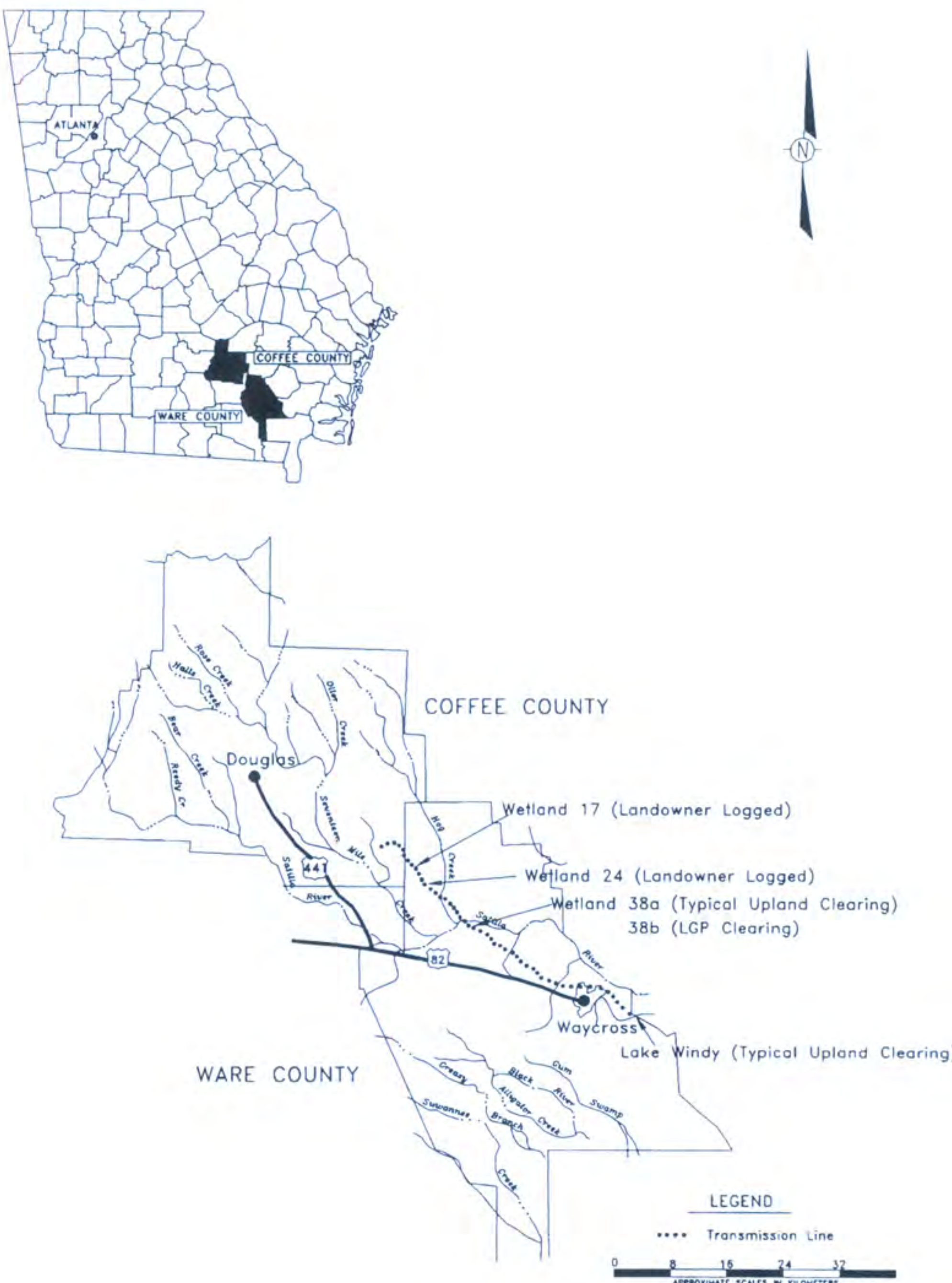



Fig. 1. Location of the mineral flat wetlands evaluated with the Hydrogeomorphic Approach to Functional Assessment.

techniques. The results of the functional assessment were used to provide documentation to the COE on changes in wetland function due to mechanized land clearing.

## METHODS

### Study sites

In 1992, Oglethorpe Power Corporation proposed constructing a 37 km transmission line ROW in the southeastern Coastal Plain of Georgia. The proposed route crossed 59 ha of jurisdictional wetlands, 23 ha of which were mineral flat wetlands containing pine plantations (Fig. 1). Due to concerns raised by the COE and US Fish & Wildlife about the number of jurisdictional wetlands crossed by the proposed route, an HGM functional assessment was conducted to evaluate changes in wetland function and clearing techniques with respect to change in wetland function.

The climate of the region is temperate, with long, hot summers and short, cool winters (Rigdon 1988). The average annual rainfall of 1290 mm is distributed relatively evenly throughout the year (Rigdon 1988). Potential evapotranspiration exceeds rainfall during June to October in normal years (Table 1).

**Table 1. Climatic data for mineral flat wetlands in the southeastern Coastal Plain of Georgia. Rainfall and potential evapotranspiration are based on 30-year normal data for Douglas, Georgia**

| Month | Rainfall (mm) | PEt[1] (mm) |
|---|---|---|
| January | 108 | 14 |
| February | 111 | 17 |
| March | 114 | 40 |
| April | 93 | 71 |
| May | 113 | 110 |
| June | 131 | 142 |
| July | 155 | 162 |
| August | 154 | 152 |
| September | 108 | 114 |
| October | 55 | 65 |
| November | 50 | 32 |
| December | 100 | 15 |
| Total | 1290 | 935 |

1. Calculated using Thornthwaite method (Dunne and Leopold 1978).

Mineral flat wetlands generally occur on a slight slope (less than 1%) and are transitional to depressional cypress swamps. Soils are formed in Pleistocene marine and fluvial sediments (Rigdon 1988). Soils observed on the sites are the Pelham series (loamy, siliceous, thermic Arenic Paleaquults) and the Sapelo series (sandy, siliceous, thermic Ultic Haplaquods). Both soils may have a perched water table during and shortly after storm events. The perched water table is commonly continuous with the shallow water table during the wetter winter months. As soil water is depleted by evapotranspiration during the summer months, the water table moves below the horizons in which perching occurs (Phillips et al. 1989, Gaskin and Nutter, in press).

The southeastern Coastal Plain of Georgia has been extensively used for forestry and agriculture. Forestry practices typically consist of site preparation including bedding of harvested sites, then planting of improved loblolly (*Pinus taeda*) or slash (*Pinus elliottii*) pine. Pine plantations are not usually thinned or prescribed burned, although intensive management has become more common as timber prices increase. Pines are harvested at 18 to 40 years. This management creates a pine overstory with a thick, predominately evergreen understory, consisting of sweet bay (*Magnolia viriginiana*), red maple (*Acer rubrum*), buckwheat tree (*Cyrilla racemiflora*), gallberry (*Ilex glabra*), and cabbage palm (*Sabal palmetto*). The herbaceous groundcover is sparse consisting of redroot (*Lachnanthes caroliniana*) and occasional pitcher plants (*Sarracenia* spp.).

Bedding at the time of planting creates extensive microtopographic relief. The litter layer is about 7 cm thick. There are few snags and large woody debris. This lack of dead woody biomass is typical of intensively managed plantations. Pine flatwoods are used by a number of wildlife species for cover and feeding. However, the edge between the pine flatwoods and cypress swamps are used by a greater number of species than the flatwoods themselves (Harris and Vickers 1984).

### HGM functional assessment

The wetlands evaluated were classified by HGM as mineral flats based on the flat geomorphic position, precipitation as the dominant water source, and strong vertical fluctuation as the primary hydrodynamic. The wet pine plantations in the southeastern Coastal Plain of Georgia form a subclass within the mineral flat class. Models of the functions identified in the mineral flat subclass were developed to predict the level of function based on Rheinhardt et al. (1995) (Table 2). These models consist of variables that are evaluated using indicators, which are easily observed or measured features of the wetland (Brinson et al. 1995) (Table 3). Reference standards for each variable are developed based on data collected from wetlands with "the highest level of functioning possible for a wetland class within the constraints of disturbance history and land use of the wetland class in the region" (Brinson et al. 1995). Reference standards can be developed from field and published data (Brinson et al. 1995). In the mineral flat subclass in southeastern Georgia, intensive forestry practices limit the ecosystem to a mid-successional stage. This stage represents the highest level of function or the reference standard for the subclass.

The current version of HGM suggests 20 or more reference wetlands are necessary to establish reference standards and develop scaling for the variables. The

**Table 2. The functions identified and models developed for the mineral flat class in southeastern Coastal Plain of Georgia. Models were based on Rheinhardt et al. (1995) and Brinson et al. (1995).**

| Functional group | Function | Model |
|---|---|---|
| Hydrologic | Short-term surface water storage | Index = $(V_{NDITCH} + V_{SOIL})/2$ |
| | Long-term surface water storage | Index = $(V_{SURWAT} + V_{MICRO} + V_{NDITCH})/3$ |
| | Subsurface storage of water | Index = $((V_{WTF} + V_{NDITCH})/2 + V_{SOIL})/2$ |
| Biogeochemical | Nutrient cycling | Index = If $(V_{BTREE} + V_{SHRUB} + V_{HERB})/3$ $(V_{SNAGS} + V_{WD} + V_{LITTERD})/3$ then $(V_{SNAGS} + V_{WD} + V_{LITTERD})/3$; otherwise $(V_{BTREE} + V_{SHRUB} + V_{HERB})/3$ |
| | Exports carbon | Index = $(V_{BTREE} + V_{LITTERD} + V_{SNAGS} + V_{WD})/4$ |
| | Organic carbon storage | Index = $((V_{SOIL} + V_{LITTERD})/2 + (V_{BTREE} + V_{SHRUB} + V_{HERB})/3 + (V_{SNAGS} + V_{WD})/2)/3$ |
| Habitat | Maintain characteristic plant communities | Index = $(V_{COMP} + V_{GAPS} + V_{BTREE})/3$ |
| | Maintain spatial habitat structure | Index = $(V_{SNAGS} + V_{MATUR} + V_{STRATA} + V_{PATCH} + V_{GAPS})/5$ |
| | Maintain food webs | Index = $((V_{COMP} + V_{STRATA} + V_{BTREE})/3 + (V_{SNAGS} + V_{WD} + V_{LITTERD})/3 + (V_{NDITCH} + V_{SOIL})/2)/3$ |

**Table 3. Indicators used for the HGM functional assessment in the mineral flat wetland in the southeastern Georgia Coastal Plain**

Hydrologic Functional Group
- Percent cover of macrotopography
- Percent cover of microtopography
- Percent cover of inundation
- Depth to saturation
- Height of watermarks, bryophyte/lichen lines, silt lines, drift/wrack lines
- Presence of seeps
- Presence of active erosional surfaces on adjacent uplands
- Soil textures
- Depth to restrictive horizon
- Redoximorphic features
- Published permeabilities

Biogeochemical Functional Group
- Soil textures
- Depth of organic horizons
- Redoximorphic features
- Depth of litter layer
- Degree of decomposition of litter layer
- Presence of woody debris
- Percent cover of epiphytes, floating or submerged plants
- Presence of mycorrhizae and fungi

Habitat Functional Group
- Basal area of dominant trees
- Percent cover of shrub/woody vine layer
- Percent cover of herbaceous groundcover
- Species list of dominants in each vegetation layer
- Number of layers in canopy/subcanopy
- Stand age
- Density of standing dead trees (0.1 ha plot)
- Presence of logs in several stages of decomposition
- Number of nesting cavities, nests etc. (0.1 ha plot)
- Presence of vegetation density gradients
- Percent cover of canopy gaps
- Presence of contiguous cover/corridors between wetland/upland
- Animal species/ sign observed

reference wetlands should include the range of variability expected across the subclass (Brinson et al. 1995). The transmission line assessment was conducted early in the development of the HGM approach and no extensive data on mineral flat wetlands were available. Consequently, a paired wetland approach was used to evaluate changes in function. Functional assessments were conducted on reference wetlands before the ROW was cleared or at least 30 m off the existing ROW near the ROW wetlands evaluated. Data from the functional assessment and published data were used to develop the reference standards (Table 4). The index assigned to each reference standard is 1.0. The variables were scaled using the approach described in the HGM Riverine Guidebook (Brinson et al. 1995).

The functional performance of *project wetlands*, or wetlands that have been disturbed, is compared to the reference standard of that wetland subclass. In this

**Table 4. Reference standard for functional index of 1.0 developed for the mineral flat demonstration wetland in the southeastern Georgia Coastal Plain**

| Model | Variable | Reference standard |
|---|---|---|
| $V_{BTREE}$ | Basal area of trees | Mid-successional forest; basal area of trees > 10 cm dbh; 80% of 23 $m^2$/ha or greater |
| $V_{COMP}$ | Species composition | Three of dominant species in each of the four strata match 3 of the 4 dominants in equivalent reference standard strata |
| $V_{GAPS}$ | Canopy gaps | Few openings in the forest canopy due to windthrow or death of trees |
| $V_{HERB}$ | Herbaceous plant density, biomass or cover | Sparse herbaceous groundcover; < 25% of wetland surface |
| $V_{LITTERD}$ | Forest floor depth | Depth of forest floor 80–120% of 7.6 cm |
| $V_{MATUR}$ | Abundance of mature trees | Density of mature trees; one or more trees 36 cm dbh or greater in 10 factor prism variable plot |
| $V_{MICRO}$ | Microtopographic complexity | Visual estimates indicate microtopographic relief is moderate; 50% of wetland surface |
| $V_{NDITCH}$ | Absence of ditches | Ditches greater than 30 cm depth absent in or near the wetland |
| $V_{PATCH}$ | Vegetation patchiness | Vegetation occurs in mosaic of density gradients |
| $V_{SHRUB}$ | Shrub density | Dense shrub layer; stem density 2,500 st/ha or greater |
| $V_{SNAG}$ | Snags | Few to no standing dead trees |
| $V_{SOIL}$ | Undisturbed forest floor/soil | Undisturbed; forest floor intact |
| $V_{STRATA}$ | Vegetation strata | Number of vertical strata 3 |
| $V_{SURWAT}$ | Indications of surface water presence | In undisturbed soil, restrictive soil horizon within 30 cm of soil surface with sparse herbaceous vegetative cover, presence of surface water during the growing season for 10–40% of surface |
| $V_{WD}$ | Woody debris | Woody debris rare |
| $V_{WTF}$ | Water table fluctuation | Range of water table fluctuation between 75% and 125% of 1.5 m including inundation and subsurface drawdown |

study, the project wetlands were located in the ROW. Changes from the reference standard were assigned indices of 1.0 to 0 based on the models. Although some wetland alterations can increase the performance of a particular function, HGM assumes the increase is not sustainable. Consequently, the indices for a project wetland may not be greater than 1.0 (Brinson et al. 1995).

A *project target*, which is the level of function a wetland can indefinitely sustain, was also established for ROW wetlands. Because the mineral flat HGM model assumes the mid-successional stage of a wetland has the highest overall level of ecosystem function, the project target was developed to most closely resemble that stage. The project target for the ROW in a mineral flat wetland is a shrub/scrub stand with as many of the original native species present as possible, and other native species that typically dominate mineral flat wetlands with shrub/scrub vegetation. The hydrologic connection between the ROW wetland and upland, as well as the ROW wetland and any streams or depressional swamps, remains undisturbed. There is as little disturbance as possible to the forest floor and soils.

Maintenance and safety require vegetation not grow higher than 4.5–6.0 m in the ROW and access be left for emergencies. Wetland ROWs in southeast Georgia are typically recleared every three to five years to maintain these conditions. These requirements dictate the project target for vegetation and habitat functions in the ROW is less than the reference standards represented by the forested reference wetlands.

To evaluate the overall change in function at a ROW wetland due to a particular clearing method, an aggregate departure from the reference standard (percent) was calculated. The departure from reference for each wetland function was summed and multiplied by 100 to represent percent. Aggregate departure from the project target for each site was also calculated in a similar manner to evaluate the difference in overall level of function from the goal for ROW wetland function.

### Clearing and construction techniques

Functional assessments were conducted in five mineral flat wetlands in ROWs (Fig. 1). Clearing techniques included track crawler clearing and stump grubbing, feller-buncher clearing and skidder removal, and LGP track crawler clearing and removal. Two sites were cleared with track crawlers and had stumps removed (typical upland clearing): a site on the Lake Windy ROW which was built in 1980, and Wetland 38a on the Wilsonville–Kettle Creek ROW built in 1993. Trees in

Wetland 38a were cleared with a KG blade on a D8 crawler with 70 cm tracks. Stumps were grubbed and all slash piled by the D8. The slash was burned and the debris scattered by the D8 and then disced into the soil with a tractor on 76 cm balloon tires. The wetland was planted in browntop millet (*Panicum ramosum*) as a nurse crop and later seeded in bermudagrass (*Cynodon dactylon*). Wetland 38a was cleared under dry conditions during spring and summer of 1993. Construction traffic at Wetland 38a was not confined, although most traffic appeared to take place on an access road within the ROW. Although no records of exact clearing techniques at the Lake Windy site were available, clearing techniques similar to those used at Wetland 38a were commonly used when this ROW was built.

Wetland 38b was cleared using LGP equipment (0.07 MPa tire pressure). Trees were cleared with a KG blade on a D7 crawler with 90 cm tracks and removed to upland areas for disposal. Some slash was left within the site. Efforts were made to leave low woody shrubs and the herbaceous layer in the wetland. Construction traffic was limited to a 4.9 m wide road. The wetland was cleared under dry conditions.

Two additional sites on the Wilsonville–Kettle Creek Transmission Line had been harvested by the landowners as the easement for the ROW was being executed. These sites were used to evaluate changes in function with mechanical clearing without grubbing the stumps. Trees was cut with a feller buncher and removed by skidder to a logging deck in a nearby upland area. The exact date of harvest is not known, but harvesting appeared to have been conducted during the summer of 1992 under relatively dry conditions because deep rutting from the equipment was not observed.

## RESULTS

Clearing the ROW by typical upland clearing techniques created the greatest changes to wetland function (Table 5). The models indicate large changes in all habitat functions due to the conversion of mid-successional forest to an early successional state, and the initial replacement of all native species with millet and bermudagrass. Disruption in the soil and litter layer caused the indices for hydrologic and biogeochemical functions to be lower than the reference. The HGM models predict these changes affect the ability of the wetland to store water in the surface and subsurface. The microtopography of the wetland was reduced, which decreased the index for long-term surface water storage. The soil disturbance and complete removal of vegetation, which reduces evapotranspiration, created a lower index for subsurface water storage. The HGM models also predicted large changes in biogeochemical functions due to the disruption of the characteristic vegetation and organic carbon storage pools. The model assigns a 0 index to nutrient cycling. This is due to the complete replacement of native vegetation, which implies although nutrient cycling does occur on the site, those processes are radically changed from the processes in the reference forested stand.

The changes seen in Wetland 38a and the Lake Windy site were similar (Table 5). Changes in habitat functions have been maintained over the past 17 years due to periodic mowing for ROW maintenance.

The mineral flat sites logged by the landowners also had large changes in function, but the indices for biogeochemical and habitat functions were higher than the wetlands cleared by typical upland techniques (Table 5). The

**Table 5. Results of HGM assessment in the mineral flat subclass of the southeastern Georgia Coastal Plain**

| Function | Reference standard | Project[2] target | Typical upland clearing 38a | Typical upland clearing Lake Windy line | Landowner logged. Wetland 17 and 24 | LGP clearing 38b |
|---|---|---|---|---|---|---|
| **Hydrologic Functions** | | | | | | |
| Short-term surface water storage | 1.0 | 0.8 | 0.5 | 0.6 | 0.6 | 0.8 |
| Long-term surface water storage | 1.0 | 0.8 | 0.4 | 0.5 | 0.7 | 0.7 |
| Subsurface water storage | 1.0 | 0.8 | 0.4 | 0.6 | 0.4 | 0.8 |
| **Biogeochemical Functions** | | | | | | |
| Nutrient cycling | 1.0 | 0.3 | 0 | 0.1 | 0.2 | 0.1 |
| Exports carbon | 1.0 | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 |
| Organic carbon storage | 1.0 | 0.5 | 0.2 | 0.2 | 0.4 | 0.4 |
| **Habitat Functions** | | | | | | |
| Maintains characteristic plant community | 1.0 | 0.03 | 0 | 0 | 0.03 | 0.03 |
| Maintains spatial habitat structure | 1.0 | 0.5 | 0.2 | 0.2 | 0.2 | 0.3 |
| Maintains food webs | 1.0 | 0.5 | 0.3 | 0.3 | 0.4 | 0.5 |
| Aggregate departure from reference | | 49% | 73% | 75% | 64% | 55% |
| Aggregate departure from project target | | | 50% | 44% | 30% | 13% |

1. Percent departure is cumulative based on reference standard.
2. Project target determined by construction and maintenance constraints.

logged wetlands had smaller changes in herbaceous groundcover, depth of litter layer and the amount of woody debris left on the site, which contributed to the slightly higher index. The predicted changes in hydrologic functions were also smaller than those for the wetland cleared with typical upland techniques (Wetland 38a) due to less soil disturbance.

The least change in function was predicted for Wetland 38b, which was cleared with LGP crawlers when the water table was at least 70 cm below the surface (Table 5). Use of LGP crawlers minimized disturbance to the soil and herbaceous layer. Rutting in this wetland was confined to the access road where several passes of machinery had occurred. The HGM models predicted small changes in wetland hydrologic functions compared to the reference due to the minimal soils disturbance. Indices for biogeochemical and habitat functions were slightly higher than for the other clearing methods due to minimal soil disturbance, the presence of an herbaceous layer and some small shrubs.

Changes in wetland function can also be compared to the project target, which represents the highest level of function that can be sustained in the wetland with the permanent alterations required by maintenance. Again, the wetlands cleared with typical upland techniques had the greatest departure from the project target. The LGP clearing had minimal departure form the project target, particularly in the hydrologic functions.

## DISCUSSION AND CONCLUSIONS

The HGM assessment indicates the habitat functions, such as spatial habitat structure, have the greatest change in function due to the conversion of mid- successional forest to an early successional stage. This conversion is a construction and maintenance constraint of building a transmission line and cannot be avoided. Clearing techniques can do little to minimize these changes.

Clearing techniques can minimize disturbance to soils and forest floor. The forest harvesting literature shows grubbing stumps and the intensive working of the soil alters soil structure and hydraulic conductivity, can change redox and organic matter decomposition rates, and increase soil temperatures (Aust et al. 1991, Aust and Lea 1992, Prichett 1987, Trettin et al. 1996, Aust and Lea 1991).

The HGM assessment indicates mechanized land clearing with LGP equipment can have minimal effects on hydrologic functions and most of the biogeochemical functions by minimizing soil and herbaceous layer disturbance. The HGM results were supported by data from physical measurements in Wetland 38a and 38b that showed higher soil surface temperatures and slower recovery of native species in the wetland cleared with typical upland techniques (Gaskin and Nutter, in press).

Because the functional assessment was conducted shortly after the ROW was constructed, the indices should reflect the lowest level of function that will occur, and function should recover over time and approach the project target. Due to the small changes in hydrologic functions and the residual native community left at the LGP cleared site, this wetland should approach the project target rapidly.

Mineral flat wetlands are extensive in southeastern Coastal Plain of Georgia. These wetlands are not as highly valued by the regulatory community as riverine wetlands or depressional cypress swamps. This is reflected in the lower factors used in calculating mitigation credits (U.S. Corps of Engineers et al. 1996) and the Memorandum to the Field (Corps and EPA Regulatory Program Chiefs 1995) stating mineral flat wetlands do not require permitting for silvicultural activities.

Results of the HGM assessment in these mineral flat wetlands indicated LGP clearing creates small changes in hydrologic and biogeochemical functions, and a small departure from the project target. These results indicate mineral flat wetlands can be mechanically cleared with LGP equipment under dry soil conditions with minimal effects; consequently, mitigation under NWP 12 or an Individual 404 Permit should not be required.

## ACKNOWLEDGEMENTS

We wish to thank the Oglethorpe Power Corporation and the Electric Power Research Institute for supporting this work. Many people gave us extensive inputs and greatly improved the project, including Christie Johnson, Stacy Patton, Steve McIntosh, John Goodrich-Mahoney, Phil Freshley, Larry Morris, David Newman and Karl Miller.

## REFERENCES

Aust, W.M. and R. Lea. 1991. Soil temperature and organic matter in a disturbed forested wetland. Soil Science Society of America Journal, 55: 1741–1746.

Aust, W.M., T.W. Reisinger, B.J. Stokes, and J.A. Burger. 1991. Wide tired skidders operating on wetland sites — preliminary results. In: Proceedings of the American Society of Agricultural Engineers Conference, Forestry and Environment Engineering Solutions, New Orleans, Louisiana, 5–6 June. B.J. Stokes and L. Cynthia, eds. American Society of Agricultural Engineers Publication No. 09-91, pp. 41–53.

Aust, W.M. and R. Lea. 1992. Comparative effects of aerial and ground logging on soil properties in a tupelo-cypress wetland. Forest Ecology and Management, 50: 57–73.

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. US Army Corps of Engineers; Wetlands Research Program Technical Report WPR-DE-4. US Army Corps of Engineers; Waterways Experiment Station; Vicksburg, MS. 101 pp.

Brinson, M.M., F.R. Hauer, L.C. Lee, W.L. Nutter, R.D. Rheinhardt, R.D. Smith, and D. Whigham. 1995. Guidebook for application of hydrogeomorphic assessments to riverine wetlands. U.S. Army Corps of Engineers; Wetlands Research Program Technical Report WRP-DE-11. US Army Corps of Engineers; Waterways Experiment Station; Vicksburg, MS. 113 pp.

Comerford, N.B., A. Jerez, A.A. Freitas, and J. Montgomery. 1996. Soil water table, reducing conditions, and hydrologic regime in a Florida flatwoods landscape. Soil Science, 161(3): 194–199.

Corps and EPA Regulatory Program Chiefs. Memorandum to the Field. 1995. Application of Best Management Practices to mechanical silivicultural site preparation activities for the establishment of pine plantations in the Southeast. United States Environmental Protection Agency, United States Army Corps of Engineers, Washington, DC.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, New York, NY. pp. 136–138.

Gaskin, J.W. and W.L. Nutter. Clearing jurisdictional wetlands: analysis of changes in wetland functions. RP 9057-01. Electric Power Research Institute; Palo Alto, California. In press.

Harris, L.D. and C.R. Vickers. 1984. Some faunal community characteristics of cypress ponds and changes induced by perturbations. In: Cypress Swamps. K.C. Ewel and H.T. Odum eds. University Presses of Florida, Gainesville, Florida. pp. 171–185.

Phillips, L.P., N.B. Comerford, D.G. Neary, and R.S. Mansell. 1989. Simulation of soil water above a water table in a forested spodosol. Soil Science Society of America Journal, 53: 1236–1241.

Prichett, W.L. and R.F. Fisher. 1987. Properties and Management of Forest Soils. 2nd edn. John Wiley & Sons, New York, NY.

Rigdon, T.A. 1988. Soil survey of Atkinson, Bacon, and Coffee Counties, Georgia. US Dept. Agriculture; Natural Resources Conservation Service, Douglas, Georgia.

Rheinhardt, R., M.M. Brinson, and P.M. Farley. 1995. A preliminary reference data set for forested flats in North Carolina and its application to wetland functional assessment. Unpublished manuscript. East Carolina University, Greenville, North Carolina.

Taylor, J.R., M.A. Cardamone, and W.J. Mitsch. 1990. Bottomland hardwood forests: their functions and values. In: Ecological Processes and Cumulative Impacts Illustrated by Bottomland Hardwood Wetland Ecosystems. J.O. Gosselink, L.C. Lee, and T.A. Muir eds. Lewis Publishers, Chelsea, Michigan.

Trettin, C.C., M. Davidian, M.F. Jurgensen, and R. Lea. 1996. Organic matter decomposition following harvesting and site preparation of a forested wetland. Soil Science Society of America Journal, 60: 1994–2003.

U.S. Army Corps of Engineers Savannah District, U.S. Environmental Protection Agency Region IV, U.S. Fish and Wildlife Service Southeast Region, and Georgia Department of Natural Resources. 1996. Guidelines on the establishment and operation of mitigation banks in Georgia, Appendix B Standard operating procedure for compensatory mitigation plans. U.S. Army Corps of Engineers, Savannah, Georgia.

## *BIOGRAPHICAL SKETCH*

***Julia W. Gaskin***

*Earth Systems Associates, Ltd., 1073 S. Milledge Ave., Athens, GA 30605, USA*

Ms. Gaskin has worked as an environmental scientist for the past nine years with Earth Systems Associates, Ltd. She has a B.S. from Duke University and an M.S. from the University of Georgia. Ms. Gaskin specializes in soils and wetland science.

***Wade L. Nutter***

*University of Georgia*

Dr. Nutter is a Professor of Forest Soils and Hydrology at the University of Georgia and President of Earth Systems Associates, Ltd. He is a member of the national team to develop the Hydrogeomorphic Approach to Functional Assessment for the U.S. Army Corps of Engineers.

# Powerline Easements as Refugia for State Rare Seepage and Pineland Plant Taxa

**Philip M. Sheridan, Steve L. Orzell, and Edwin L. Bridges**

Field surveys of selected powerline easements on the inner coastal plain of Georgia, Maryland, and Virginia uncovered significant rare seepage and pineland plant taxa in comparison to the surrounding fire-suppressed and human altered landscapes. Surveys of selected powerline easements resulted in the discovery of 65 state rare plant species from 24 counties in three states. Twenty-two state rare plant species are documented on powerline easements for Georgia, 12 for Maryland, and 31 for Virginia. Two state endangered and three state threatened plants were found in Georgia powerline easements while 3 state endangered and two state threatened were found in Maryland. Rare plant taxa occur on powerline easements for several reasons: right-of-way management strategies have replaced natural disturbances; naturally open herbaceous seeps harboring rare plant taxa were crossed by powerlines; seeds were dispersed to the easement by wind or other vectors; plants were present in low numbers, dormant or in seed banks prior to powerline easement clearing; or a combination of some or all of these factors. Periodic mechanical clearing of brushy vegetation to maintain powerline easements can replace natural disturbances such as fire and beaver activity and thereby may allow some disturbance adapted rare plants to persist that might otherwise be locally extirpated through fire suppression and subsequent woody invasion of open space habitat niches. Powerline rare plant refugia might serve as a local measure of biodiversity in regions where the surrounding natural vegetation has been highly altered or subjected to fire suppression and seepage bog or pineland plants are now found in powerline easements.

*Keywords*: Powerlines, rights-of-way, biodiversity, state rare plants, pitcher plant bogs

## INTRODUCTION

Rights-of-way habitats (e.g. railroads, roadsides, powerlines, fencelines, etc.) have historically been surveyed by botanists to discover rare plant populations, primarily due to their easy access. One of the early pioneers of this method was the botanist Roland Harper who used railroad rights-of-way as a method for finding rare plant populations (Core 1970, Harper 1904a,b, 1905a,b, 1907). We became interested in powerline easements as rare plant habitats when we observed that rare herbaceous seepage plants were often locally restricted to areas underneath powerlines. We therefore began surveying selected powerline easements to locate and assess the potential for rare plant occurrences. We suspected that powerline easements serve as both refugia for rare plant populations and as a measure of local plant biodiversity, particularly in regions where the surrounding landscape has been highly altered or subject to fire suppression.

Seepage habitats in the southeastern United States are a type of wetland characterized by a distinctive flora of sundews (*Drosera*: Droseraceae), bladderworts (*Utricularia*: Lentibulariaceae), butterworts (*Pinguicula*: Lentibulariaceae) and pitcher plants (*Sarracenia*: Sarraceniaceae) (Folkerts 1982). In the southeastern United States they typically occur on side valley slopes or headwaters of small tributaries and are permanently fed by diffuse telluric groundwater (Bridges and Orzell 1989, Folkerts 1991). Seepage habitats located at heads of stream branches in Maryland and Virginia have been classified as magnolia bogs (McAtee 1918). Seepage wetland soils are typically acidic and are of either organic or mineral composition. The herbaceous flora requires periodic fires or some form of natural disturbance (e.g., beaver activity) to maintain the diversity of the herbaceous species rich groundcover (Bridges and Orzell 1989, Fenwick and Boone 1984, Frost and Musselman 1987, Frost 1993, 1995, Folkerts 1982, Rudis and Skinner 1991, Waldrop et al. 1992).

## MATERIALS AND METHODS

Our study was confined to southern Georgia and the inner coastal plain of Maryland and Virginia (Fig. 1). Field study sites were determined by locating powerline rights-of-way through potential habitats on USGS 7.5 minute series topographic maps. Accessible sites were evaluated during field surveys. The vascular flora of each site was inventoried, sometimes with repeat site visits, and representative plant collections were made and prepared as herbarium voucher specimens.

Voucher specimens are deposited at the following herbaria: Fairchild Tropical Gardens (FTG), George Mason University (GMUF), and Virginia Commonwealth University (VCU). Each site is coded by an alpha-numeric site code consisting of state (first two letters), county (next four letters), and site identification number. For example, VADINW001 is the first site visited in Dinwiddie County, Virginia. Additional site-specific locational information is available from the authors.

Plant nomenclature and identification follows either Kartesz (1994) or Wunderlin, Hansen and Bridges (Vascular Flora of Central Florida, unpublished manuscripts). Plant determinations were performed by the authors as well as Dr. Ted Bradley (curator-GMUF), Mark Strong (United States herbarium) and Robert Wright. Rare species status was determined by consulting state rare plant lists and/or publications (Georgia Natural Heritage Program 1991, 1993, Patrick et al. 1995, Ludwig 1997, Maryland Natural Heritage Program 1994). Global and state ranking of plants follows The Nature Conservancy and the respective state natural heritage ranking scheme (Table 1).

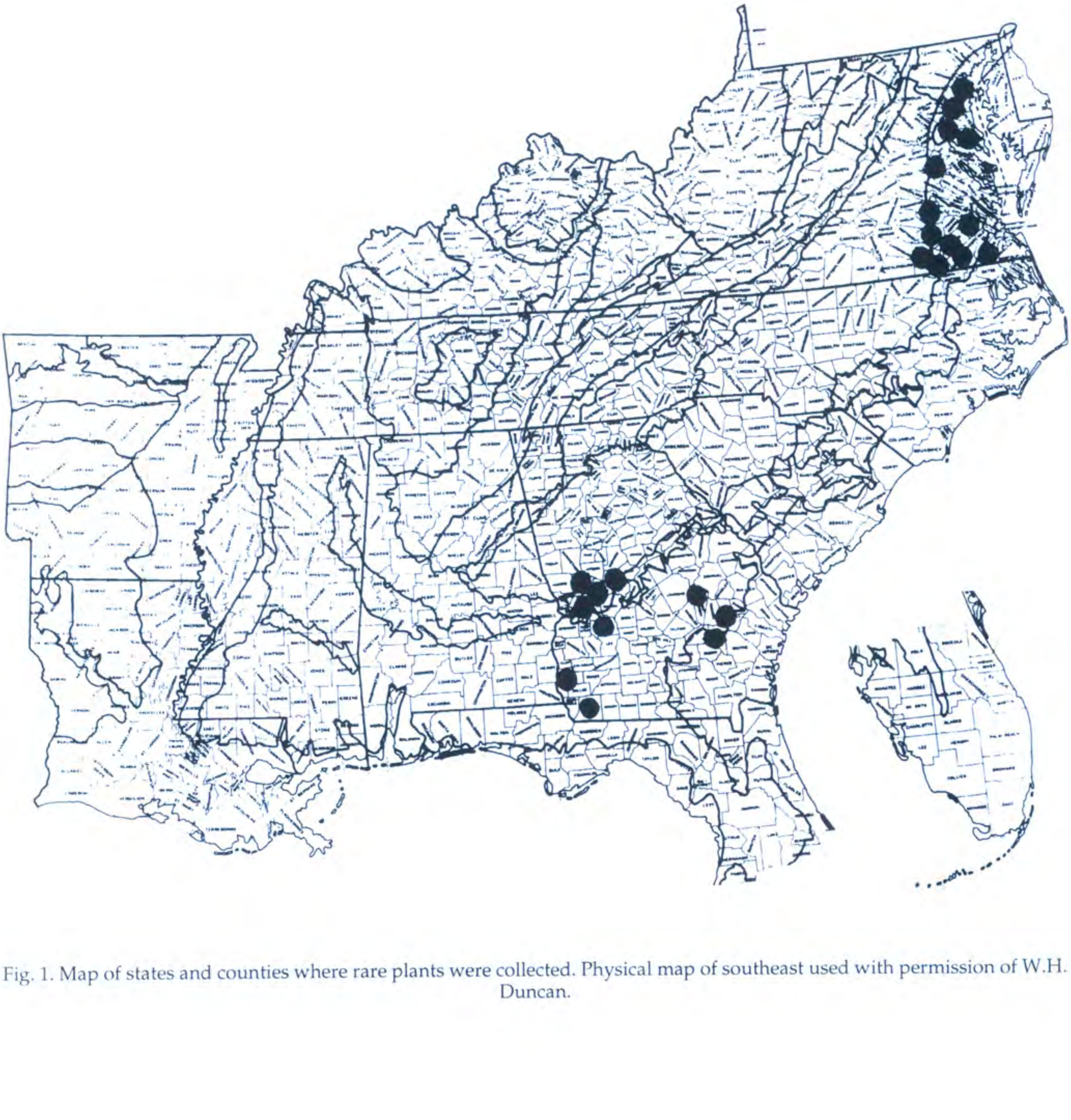


Fig. 1. Map of states and counties where rare plants were collected. Physical map of southeast used with permission of W.H. Duncan.

## RESULTS

Twenty-two state rare plant species are documented on powerline easements for Georgia, 12 for Maryland, and 31 for Virginia. Two state endangered and three state threatened plants were found in Georgia powerline easements while three state endangered and two state threatened were found in Maryland (Table 1). A maximum of 10 rare species was recorded in Virginia from VADINW001 (Figs. 2–4). No federally endangered or federally threatened listed species were found on powerline easements. Future discoveries of additional rare plant taxa and other noteworthy plants are possible since our surveys did not account for all seasonal and yearly variation present at the sites. In several cases additional rare plants were observed at some sites but specimens were not collected due to the depauperate condition of the plant material, small population size, etc.

**Table 1. List of state rare plants collected on powerline easements**

| Scientific name | State status | Global rank | State rank |
|---|---|---|---|
| Georgia: | | | |
| *Balduina atropurpurea* | N | G2G3 | S2 |
| *Chamaecyparis thyoides* | N | G4 | S2 |
| *Delphinium carolinianum* | N | G5 | S3 |
| *Eriocaulon texense* | N | G4 | S2? |
| *Helenium brevifolium* | SH | G3G4 | – |
| *Helianthus longifolius* | N | G? | S2 |
| *Kalmia carolina* | N | G5T4 | S1 |
| *Pinguicula primuliflora* | T | G4 | S1 |
| *Platanthera nivea* | N | G5 | S3 |
| *Rhododendron flammeum* | N | G3 | S3 |
| *Rhynchospora oligantha* | N | G4 | S1? |
| *Rhynchospora stenophylla* | N | G4 | S2 |
| *Sarracenia flava* | N | G4G5 | S3S4 |
| *Sarracenia minor* | N | G4 | S4 |
| *Sarracenia psittacina* | T | G4 | S2S3 |
| *Sarracenia purpurea* | E | G5 | S1 |
| *Sarracenia rubra* | E | G3 | S2 |
| *Stylisma pickeringii* var. *pickeringii* | T | G4T2T3 | S2 |
| *Warea cuneifolia* | N | G4 | S2? |
| *Xyris chapmanii* | N | G3 | S1 |
| *Xyris drummondii* | N | G3 | S1S2? |
| *Xyris scabrifolia* | N | G3 | S1S2? |
| Maryland: | | | |
| *Aster nemoralis* | N | G5 | S1 |
| *Carex collinsii* | N | G4 | S3 |
| *Carex vesicaria* | T | G5 | S1 |
| *Castanea pumila* | N | G5 | S3 |
| *Drosera capillaris* | E | G5 | S1 |
| *Eleocharis tortilis* | N | G5 | S2 |
| *Juncus caesariensis* | E | G2 | S1 |
| *Kalmia angustifolia* | N | G5 | S3S4 |
| *Rhynchospora alba* | N | G5 | S3 |
| *Rhynchospora gracilenta* | N | G5 | S3 |
| *Sarracenia purpurea* | T | G5 | S2 |
| *Smilax pseudo-china* | E | G4G5 | S1 |
| Virginia: | | | |
| *Aletris aurea* | N | G5 | S1 |
| *Asclepias rubra* | N | G4G5 | S2 |
| *Carex collinsii* | N | G4 | S3 |
| *Carex venusta* | N | G4 | S3 |
| *Carex vestita* | N | G5 | S2 |
| *Chelone cuthbertii* | N | G3 | S2 |
| *Cirsium virginianum* | N | G3G4 | S2 |
| *Cleistes divaricata* | N | G4 | S1 |
| *Ctenium aromaticum* | N | G5 | S1 |
| *Drosera brevifolia* | N | G5 | S3 |
| *Drosera capillaris* | N | G5 | S3 |
| *Eriocaulon decangulare* | N | G5 | S2 |
| *Eriophorum virginicum* | N | G5 | S2S3 |
| *Helenium brevifolium* | N | G3G4 | S2 |
| *Hypoxis micrantha* | N | G4 | S3 |
| *Juncus caesariensis* | N | G2 | S2 |
| *Kalmia angustifolia* | N | G5 | S2 |
| *Lachnocaulon anceps* | N | G5 | S2 |
| *Lycopodiella caroliniana* var. *caroliniana* | N | G5T4 | S1 |
| *Platanthera blephariglottis* | N | G4G5T3T4 | S1 |
| *Pogonia ophioglossoides* | N | G5 | S3 |
| *Rhynchospora rariflora* | N | G5 | S3 |
| *Sabatia brachiata* | N | G5? | S3 |
| *Sabatia campanulata* | N | G5 | S2 |
| *Sarracenia flava* | N | G5? | S1 |
| *Sarracenia purpurea* | N | G5 | S2S3 |
| *Scleria minor* | N | G4 | S2 |
| *Tetragonotheca helianthoides* | N | G5 | S1 |
| *Utricularia geminiscapa* | N | G4G5 | S3 |
| *Zigadenus densus* | N | G5 | S1 |
| *Zigadenus glaberrimus* | N | G5 | S1 |

State Status: N = none; E = state endangered; T = state threatened; H = infers that the species has not been observed in the wild for 20 or more years.
Global Rank: G2 = globally imperiled, 6–20 populations; G3 = very rare and local throughout its range or found locally in a restricted range or because of other factors making it vulnerable to extinction, 21–100 populations; G4 = apparently secure globally although it may be rare in parts of its range, 100–1000 populations; G5 = demonstrably secure globally, though it may be quite rare in parts of its range, 1000+ populations.
T# = the rank of a subspecies or variety.
State Rank: S1 = critically imperiled in the state, 1–5 populations; S2 = imperiled in the state, 6–20 populations; S3 = rare or uncommon in the state, 21–100 populations.

Fig. 2. Powerline easement at VADINW001, 1987. Ten rare seepage plants have been recorded from this one acre site.

Fig. 3. White-fringed orchid (*Platanthera blephariglottis*) and yellow pitcher plant (*Sarracenia flava*) growing in right-of-way at VADINW001, 1987.

Fig. 4. Toothache grass (*Ctenium aromaticum*) growing at its northern limit at VADINW001, 1987. One of only two sites presently known in Virginia are from powerline easements.

Each plant collection is listed in alphabetical order first by state, then by genus and species. Following the scientific name is the authority, common name, collection site code, date of collection, collector(s), and herbarium acronym where the specimen is deposited. Collections for 1996 remain in the senior author's personal herbarium awaiting deposit to a public facility.

### Georgia collections

*Balduina atropurpurea* (Harper) Small — Purple balduina. GATATT010: 21 Aug 1992, *Sheridan, Troup, Patrick, Determan, Jenkins and Nordman 1258* (FTG).

*Chamaecyparis thyoides* (L.) B.S.P. — Atlantic white cedar. GATAYL001: 6 May 1987, *Bridges and Orzell 5171* (FTG).

*Delphinium carolinianum* Walt. — Carolina larkspur. GACRAW001: 27 May 1994, *Sheridan and Determan 1574* (FTG).

*Eriocaulon texense* Koern. — Texas pipewort. GAMARI002: 10 April 1991, *Sheridan 685* (FTG).

*Helenium brevifolium* (Nutt.) Wood — Shortleaf sneezeweed. GATAYL001: 6 May 1987, *Bridges and Orzell 5168* (FTG).

*Helianthus longifolius* Pursh — Longleaf sunflower. GATAYL001: 9 Sept 1990, *Bridges and Orzell 15036* (FTG) GATAYL006, 8 Sept 1990, *Bridges and Orzell 14993* (FTG).

*Kalmia carolina* Small — Carolina sheep-laurel. GATAYL001: 6 May 1987, *Bridges and Orzell 5167* (FTG).

*Pinguicula primuliflora* Wood & Godfrey — Southern butterwort. GAMARI002: 10 April 1991, *Sheridan 684* (FTG).

*Plantanthera nivea* (Nutt.) Luer — Snowy orchid. GAEARL001A: 14 June 1994, *Sheridan 1682* (FTG).

*Rhododendron flammeum* (Michx.) Sarg. — Oconee azalea. GASUMT001: 11 April 1991, *Sheridan 689* (FTG).

*Rhynchospora oligantha* Gray — Beakrush. GAMARI001: 9 Sept 1990, *Bridges and Orzell 15074* (FTG).

*Rhynchospora stenophylla* Chapman — Beakrush. GACRAW001: 8 June 1989, *Sheridan and Scholl 183 and 188* (FTG); 8 Sept 1990, *Bridges and Orzell 14941* (FTG). GACRAW005: 18 June 1994, *Sheridan and Patrick 1726* (FTG). GADECA008: 13 June 1994, *Sheridan 1672* (FTG). GATALB001: 9 Sept 1990, *Bridges and Orzell 15150* (FTG). GATAYL006, 3 June 1989, *Sheridan and Scholl 94* (FTG); 8 Sept 1990, *Bridges and Orzell 14997* (FTG). GATAYL008: 8 Sept 1990, *Bridges and Orzell 15024* (FTG).

*Sarracenia flava* L. — Yellow pitcher plant. GATATT010: 21 Aug 1992, *Sheridan, Troup, Patrick, Determan, Jenkins and Nordman 1232* (FTG). GATREU001: 9 April 1991, *Sheridan 677* (FTG).

*Sarracenia minor* Walt. — Hooded pitcher plant. GAAPPL002: 7 April 1991, *Sheridan 652* (FTG).

*Sarracenia psittacina* Michx. — Parrot pitcher plant. GAEARL002: *Sheridan 1155* (FTG).

*Sarracenia purpurea* L. — Purple pitcher plant. GATATT010: 21 August 1992, *Sheridan, Troup, Patrick, Determan, Jenkins, Nordman 1231* (FTG).

*Sarracenia rubra* Walt. — Sweet pitcher plant. GACRAW001: 8 Sept 1990, *Bridges and Orzell 14933* (FTG). GAMARI001: 9 Sept 1990, *Bridges and Orzell 15080* (FTG); 2 Nov 1991, *Sheridan 1109* (FTG). GAMARI002: 14 March 1990, *Sheridan 510* (FTG); 10 April 1991, *Sheridan 680* (FTG). GATALB001: 22 Sept 1987, *Sheridan and Scholl 452* (GMUF); 9 Sept 1990, *Bridges and Orzell 15141* (FTG); 1 Nov 1991, *Sheridan 1108* (FTG). GATAYL001: 6 May 1987, *Bridges and Orzell 5169* (FTG). GATAYL006: 21 Sept 1987, *Sheridan and Scholl 450* (GMUF); 8 Sept 1990, *Bridges and Orzell 14995* (FTG). GATAYL008: 21 Sept 1987, *Sheridan and Scholl 451* (GMUF); 8 Sept 1990, *Bridges and Orzell 15021* (FTG). GATAYL017: Sept 1987, *Sheridan and Scholl 449* (GMUF).

*Stylisma pickeringii* (Torr. ex M.A. Curtis) Gray var. *pickeringii* — Pickering morning-glory. GATALB002: 9 Sept 1990, *Bridges and Orzell 15166* (FTG). GATAYL006: 3 June 1989, *Sheridan and Scholl 71* (FTG); 8 Sept 1990, *Bridges and Orzell 14980* (FTG); 18 June 1994, *Sheridan 1717* (FTG).

*Warea cuneifolia* (Muhl. ex Nutt.) Nutt. — Warea. GATALB001: 9 Sept 1990, *Bridges and Orzell 15125* (FTG). GATAYL006: 8 Sept 1990, *Bridges and Orzell 14979* (FTG).

*Xyris chapmanii* Bridges & Orzell-Chapman yellow-eyed grass. GAMARI001: *Bridges and Orzell 15065* (FTG).

*Xyris drummondii* Malme — Drummond yellow-eyed grass. GAMARI001: 9 Sept 1990, *Bridges and Orzell 15082* (FTG).

*Xyris scabrifolia* Harper — Harper yellow-eyed grass. GAMARI001: 9 Sept 1990, *Bridges and Orzell 15109* (FTG).

## Maryland collections

*Aster nemoralis* Ait. — Bog aster. MDANNE001: 12 Sept 1996, *Sheridan and Underwood 1973*.

*Carex collinsii* Nutt. — Collins' sedge. MDCHAR004, 12 Nov 1989, *Sheridan 367* (FTG).

*Carex vesicaria* L. — Inflated sedge. MDANNE001: 14 July 1996, *Sheridan and Underwood 1954*.

*Castanea pumila* (L.) P. Mill. — Chinquapin. MDCHAR006: 23 July 1994, *Sheridan and Strong 1737* (FTG).

*Drosera capillaris* Poir. — Pink Sundew. MDSTMA003: 21 July 1987, *Sheridan 408* (GMUF).

*Eleocharis tortilis* (Link) J.A. Schultes — Twisted spikerush. MDCHAR006: 23 July 1994, *Sheridan and Strong 1751* (FTG).

*Juncus caesariensis* Coville — New Jersey rush. MDCHAR004: 12 Nov 1989, *Sheridan 368* (GMUF). MDCHAR005: 23 Nov 1989, *Sheridan 369* (GMUF). MDCHAR006: 23 July 1994, *Sheridan and Strong 1749* (FTG).

*Kalmia angustifolia* L. — Sheep-laurel. MDPRIN002: 14 Oct 1989, *Sheridan 349* (FTG); 12 May 1990, *Sheridan 533* (FTG). MDSTMA001: 21 June 1987, *Sheridan 424* (GMUF); 22 July 1989, *Sheridan and Curlee 231* (FTG).

*Rhynchospora alba* (L.) Vahl — White beakrush. MDANNE001: 14 July 1996, *Sheridan and Underwood 1954*. MDCHAR006: 23 July 1994, *Sheridan and Strong 1747* (FTG).

*Rhynchospora gracilenta* Gray — Slender beakrush. MDSTMA001: 22 July 1989, *Sheridan and Curlee 234* (FTG).

*Sarracenia purpurea* L. — Purple pitcher plant. MDCHAR006: 23 July 1994, *Sheridan and Strong 1748* (FTG).

*Smilax pseudochina* L. — Halberd-leaved greenbrier. MDANNE001: 15 July 1996, *Sheridan, Underwood and Benassi 1968*.

## Virginia collections

*Aletris aurea* Walt. — Golden colicroot. VABRUN002: 11 July 1987, *Sheridan 422B* (GMUF). VAGREE017: 11 July 1987, *Sheridan 422A* (GMUF).

*Asclepias rubra* L. — Red Milkweed. VACHES004: 26 July 1989, *Wright 3052* (VCU).

*Carex collinsii* Nutt. — Collins' sedge. VACARO010: 27 Aug 1989, *Sheridan 300* (FTG).

*Carex venusta* Dewey — Dark green sedge. VAGREE018: 6 June 1993, *Sheridan 1435* (FTG).

*Carex vestita* Willd. — A sedge. VACHES002: 15 June 1990, *Wright 3065* (VCU).

*Chelone cuthbertii* Small — Cuthbert turtlehead. VACHES004: 26 July 1989, *Wright 3051* (VCU).

*Cirsium virginianum* (L.) Michx. — Virginia thistle. VACHES004: 2 Oct 1989 *Wright 3061* (VCU). VASUSS001: 3 Sept 1991, *Sheridan 777* (FTG).

*Cleistes divaricata* (L.) Ames — Spreading pogonia. VACHES002: *Wright 4921* (VCU). VASUFF002: 13 June 1996, *Sheridan 1910A*.

*Ctenium aromaticum* (Walt.) Wood — Toothache grass. VADINW001: 19 July 1986, *Strong and Sheridan 86-001* (GMUF).

*Drosera brevifolia* Pursh — Dwarf Sundew. VACARO018: 17 June 1991, *Sheridan 741* (FTG). VAGREE017: 11 July 1987, *Sheridan 403* (GMUF). VASOUT002: 27 April 1986, *Sheridan and Scholl 33* (GMUF). VASUFF002: 19 April 1986, *Sheridan and Scholl 35* (GMUF). VASURR001: 8 Oct 1992, *Sheridan 1342* (FTG). VASURR002: 8 Oct 1986, *Sheridan 413* (GMUF). VASUSS001: 21 May 1989, *Sheridan, Scholl and Hummer 66* (FTG). VASUSS003: 5 Oct 1985, *Sheridan 43* (GMUF). VASUSS005: 18 Nov 1990, *Sheridan 643* (FTG). VASUSS008: 13 June

1992, *Sheridan and Curlee 1173* (FTG). VASUSS010: 12 Oct 1985, *Sheridan and Scholl 41* (GMUF).

*Drosera capillaris* Poir. — Pink Sundew. VADINW001: 17 August 1985, *Sheridan 48* (GMUF); 1987, *Sheridan 402* (GMUF); 25 Oct 1992, *Sheridan and Wright 1383* (FTG). VADINW003: 17 May 1991, *Sheridan 731* (FTG); 3 Aug 1994, *Sheridan 1823* (FTG). VASUFF002: 19 April 1986, *Sheridan and Scholl 46* (GMUF). VAGREE017: 14 June 1992, *Sheridan and Curlee 1216* (FTG). VAGREE018: 3 June 1993, *Sheridan 1428* (FTG). VASUSS001: 11 July 1987, *Sheridan 407* (GMUF). VASUSS002: 23 Sept 1989, *Sheridan and Harvill 338* (FTG); 19 May 1991, *Sheridan 723* (FTG). VASUSS005: 18 Nov 1990, *Sheridan 642* (FTG); 13 June 1991, *Sheridan, Belden and Ludwig 739* (FTG). VASUSS008: 13 June 1992, *Sheridan and Curlee 1174* (FTG).

*Eriocaulon decangulare* L. — Ten-angled pipewort. VADINW001: 1987, *Sheridan 423* (GMUF); 3 Sept 1991, *Sheridan 794* (FTG).

*Eriophorum virginicum L. — Tawny cotton-grass. VACARO013: 16 Sept 1989, Sheridan and Darling 319* (FTG).

*Helenium brevifolium* (Nutt.) Wood — Shortleaf sneezeweed. VADINW001: 21 May 1989, *Sheridan, Hummer and Scholl 63* (FTG).

*Hypoxis micrantha* Pollard — Pineland yellow stargrass. VASUSS007: 19 May 1991, *Sheridan 728* (FTG).

*Juncus caesariensis* Coville — New Jersey rush. VACARO010: 22 July 1986 *Strong and Sheridan 86-009* (GMUF). VACARO011: 30 July 1994, *Strong and Sheridan 1172* (GMUF). VACARO012: 22 July 1986 *Strong and Sheridan 86-005* (GMUF); 1987, *Sheridan 430* (GMUF). VACARO013: 16 Sept 1989, *Sheridan and Darling 321* (GMUF). VACARO015: 2 Nov 1986, *Sheridan 435* (GMUF); 17 Sept 1989, *Sheridan 329* (GMUF). VACARO018: 4 Oct 1992, *Sheridan 1349* (FTG). VACHAR001: 29 July 1989, *Strong, Sheridan and Kelloff 612* (GMUF). VACHAR002: 29 July 1989, *Strong, Sheridan and Kelloff 615* (GMUF).

*Kalmia angustifolia* L. — Sheep-laurel. VACARO022: 1986, *Sheridan and Scholl 384* (GMUF).

*Lachnocaulon anceps* (Walt.) Morong — Bog-buttons. VADINW003: 10 July 1987, *Sheridan 422* (GMUF); 17 May 1991, *Sheridan 730* (FTG); 3 August 1994, *Sheridan 1822* (FTG). VAGREE017: 11 July 1987, *Sheridan 421* (GMUF); 14 June 1992, *Sheridan and Curlee 1209* (FTG). VASUSS005: 13 June 1991, *Sheridan, Belden and Ludwig 738* (FTG).

*Lycopodiella caroliniana* (L.) Pichi Sermolli var. *caroliniana* — Slender clubmoss. VACARO012: 16 Sept 1989, *Sheridan and Darling 317* (FTG). VASURR001: 8 Oct 1992, *Sheridan 1341* (FTG).

*Plantanthera blephariglottis* (Willd.) Lindl. — White-fringe orchid. VACHES001: 19 July 1987, *Sheridan 437* (GMUF). VACHES002: 26 July 1989, *Wright 3054* (VCU). VADINW001: 12 Oct 1985, *Sheridan 438* (GMUF); 1987, *Sheridan 436* (GMUF).

*Pogonia ophioglossoides* (L.) Ker-Gawl. — Rose pogonia. VASUSS004: 19 May 1991, *Sheridan 716* (FTG). VASUSS008: 13 June 1992, *Sheridan and Curlee 1177* (FTG).

*Rhynchospora rariflora* (Michx.) Ell. — Few-flowered beakrush. VAGREE017: 14 June 1992, *Sheridan and Curlee 1211* (FTG).

*Sabatia brachiata Ell. — Narrow-leaf pink. VASUSS004: 1 July 1990, Sheridan and Scholl 555* (FTG).

*Sabatia campanulata* (L.) Torr. — Slender marsh pink. VADINW001: 3 August 1994, *Sheridan 1769* (FTG). VADINW003: 3 August 1994, *Sheridan 1814* (FTG).

*Sarracenia flava* L. — Yellow pitcher plant. VADINW001: 17 August 1985, *Sheridan 23 & 24* (GMUF); 21 May 1989, *Sheridan, Scholl and Hummer 65* (FTG). VASUSS001: 11 July 1987, *Sheridan 453* (GMUF); 2 June 1990, *Sheridan and Robinson 543* (FTG).

*Sarracenia purpurea* L. — Purple pitcher plant. VACARO013: 25 May 1987, *Sheridan 378* (GMUF); 16 Sept 1989, *Sheridan and Darling 318* (FTG). VASUSS002: 23 Sept 1989, *Sheridan and Harvill 334* (FTG). VASUSS004: 1 July 1990, *Sheridan and Scholl 553* (FTG); 19 May 1991, *Sheridan 715* (FTG); 14 June 1992, *Sheridan and Curlee 1191* (FTG).

*Scleria minor* W. Stone — Slender nutrush. VADINW001: 3 Aug 1994, *Sheridan 1781* (FTG). VASUFF002: 13 June 1996, *Sheridan 1910*. VASUSS008: 13 June 1992, *Sheridan and Curlee 1187* (FTG).

*Tetragonotheca helianthoides* L. — Pineland squarehead. VACHES001: 30 June 1990, *Sheridan and Scholl 549* (FTG).

*Utricularia geminiscapa* Benj. — Hidden-fruited bladderwort. VACHAR001: 29 June 1989, *Sheridan, Strong and Kelloff 258* (FTG).

*Zigadenus densus* (Desr.) Fern. — Black snakeroot. VAGREE018: 3 June 1993, *Sheridan 1434* (FTG).

*Zigadenus glaberrimus* Michx. — Large-flowered camass. VADINW001: 3 Sept 1991, *Sheridan 788* (FTG); 3 Aug 1994, *Sheridan 1783* (FTG).

## Significance of collections

The 1987 *Helenium brevifolium* collection from Taylor County, Georgia is significant because this species was considered state historical in Georgia. No Georgia collections have been reported since the 1940s (Tom Patrick, pers. comm. 1997) and only two stations were known (Rock 1957). *Pinguicula primuliflora* and *Stylisma pickeringii* var. *pickeringii* are both Georgia state threatened species. The *S. pickeringii* var. *pickeringii* from Talbot County, Georgia represents a county record as well. Collections of *Rhynchospora stenophylla* and *Xyris chapmanii* are new additions to the flora of Georgia. The range of the state endangered *Sarracenia rubra* was expanded by finding county records on powerline easements in Crawford and Marion counties, Georgia (Fig. 5) and

Fig. 5. *Sarracenia rubra* growing in powerline right-of-way in GAMARI001, November 1991.

new site records in Taylor County, Georgia. *Sarracenia psittacina* collected in Early County, Georgia was a county record and filled a range gap in the southwestern part of the state.

In Georgia, *Balduina atropurpurea* and all *Sarracenia* are usually found in fire maintained natural areas and powerlines while *Warea cuneifolia* can be found in sandy openings in sandhills. *Hypoxis micrantha, Sabatia brachiata, Platanthera nivea* and most of the Cyperaceae and all of the Eriocaulaceae are normally found in either sand hills, pine barrens, seepage bogs or burned ecosystems and benefit from openings in powerline easements. *Delphinium carolinianum* and *Rhododendron flammeum* are not restricted to powerlines, seepages or pinelands.

The Maryland collection of *Juncus caesariensis* was a rediscovery (Sheridan 1991), since it had not been seen in Maryland since 1939 (Ware and Wieboldt 1981). *Sarracenia purpurea* and *Drosera capillaris* are new to southern Maryland and are state rare taxa.

The only surviving populations in Virginia of *Aletris aurea, Ctenium aromaticum, Lycopodiella caroliniana* var. *caroliniana, Tetragonotheca helianthoides* and *Zigadenus densus* were found on powerline easements. New populations of *Juncus caesariensis* were also discovered growing in powerline habitats as previously described (Strong and Sheridan 1991).

*Asclepias rubra, Cleistes divaricata, Chelone cuthbertii, Drosera capillaris, Eriophorum virginicum, Juncus caesariensis, Lachnocaulon anceps, Sabatia campanulata, Sarracenia flava,* and *Zigadenus glaberrimus* are now almost exclusively found on power line rights-of-way in coastal Virginia. Plants which do well in Virginia powerlines but can persist in edges, partially shaded woods, beaver ponds and borders, or wet meadows are *Cirsium virginianum, Eriocaulon decangulare, Helenium brevifolium, Pogonia ophioglossoides* and *Utricularia geminiscapa*. *Drosera brevifolia* was found so commonly along roadsides, powerlines, and in various clearings that we suggest it no longer be considered a state rare species in Virginia.

Occurrences of rare woody species such as *Castanea pumila, Chamaecyparis thyoides,* and *Kalmia angustifolia* indicate persistence of these species despite clearing methods.

## DISCUSSION

The occurrences of state rare plant species on powerline easements can be attributed to several factors:

1. Powerlines crossed rare plant habitats which were historically kept open by natural disturbance, such as fire or beaver, and are now maintained by right-of-way maintenance practices.
2. Naturally open herbaceous seeps harboring rare plant taxa were crossed by powerline easements and their associated rare plant populations have persisted.
3. Rare plants were present in low numbers, dormant or in the seed bank prior to clearing for development of the powerline easement through optimal habitat.
4. Rare plants occur elsewhere in the region and have been dispersed into the site by wind or other vectors.
5. A combination of some or all of these factors.

Periodic mechanical clearing of brushy vegetation to maintain powerline easements can replace natural disturbances, such as fire and beaver activity, and thereby may allow some disturbance adapted rare plants to persist that might otherwise be locally extirpated through fire suppression and subsequent woody invasion of open space habitat niches. Powerline easement management of vegetation tends to reduce tree and shrub layer competition thereby favoring the diverse, species rich groundcover component found in pinelands and seepage bogs. Powerline easements across environmental gradients and associated ecotones historically kept open by natural processes often have the greatest potential to harbor rare seepage and pineland plant taxa. Powerline easements which cut through landscapes with historical occurrences of herbaceous seepage bogs can serve as significant refugia for rare plant taxa (Fig. 6).

Fernald (1937) recorded several stations in Virginia for the locally abundant *Sarracenia flava* while other species such as *Tetragonotheca helianthoides* (Fernald 1940) and *Zigadenus densus* (Fernald 1939) were only found at a few or single locations. Mrs. Shands (pers. comm. 1985) reports that *S. flava* commonly occurred in cow pastures in Sussex County during the same time period as Fernald's explorations. Pederson (1941a,b) advocated a vigorous statewide fire suppression campaign which led to encroachment of herbaceous wetlands by woody vegetation. Powerlines constructed during this time period could have crossed over populations of rare plants thereby perhaps permitting their survival during an era of fire suppression. Species such as *Platanthera blephariglottis, Sarracenia flava* and *Zigadenus glaberrimus* have been locally extirpated (Frost and Musselman 1987) in Virginia where fire has been suppressed (Fig. 7).

Fig. 6. Powerline right-of-way at GATAYL006, June 1988. Mowing of powerline rights-of-way mimics natural disturbance such as fire which maintained the adjacent overgrown longleaf pine habitats in an open condition. Note hillside seepage bog plants in foreground and on toe slopes towards center of photograph. A wide variety of habitats are crossed and provide opportunity for intersection of natural openings.

Fig. 7. *Sarracenia flava* at VASUSS001, May 1987. This powerline right-of-way was established prior to 1934 and may have served as a refugia during the era of fire suppression for rare plants. All of the reproducing populations of *S. flava* in Virginia occur on powerline rights-of-way.

Fire suppression, drainage of wetlands, and agricultural and silvicultural practices have led to a loss of habitat for rare plant species in the southeastern United States (Hardin and White 1989, Walker 1993). The extirpation of the beaver, *Castor canadensis*, in many regions also led to loss of pond margin habitat for rare wetland species as well (Fenwick and Boone 1984).

The occurrence of rare plant taxa in power line bogs such as at MDANNE001 and their comparable percentage of rare species to natural sites (data not shown) may indicate that natural openings occurred on powerline rights-of-way prior to powerline installation. This hypothesis may be supported by the recent discovery of a naturally open bog approximately 3.5 km from the powerline at MDANNE001. A naturally open seepage bog was also discovered in Decatur County, Georgia nearby powerline seepage bog GADECA008 in the winter of 1996 (Sheridan and Underwood, field notes). Collections from the powerline easement at GADECA008 of *Rhynchospora stenophylla*, an obligate seepage species, support the occurrence of naturally open seepage bogs in the region. Similar rare plant occurrences fidel to herbaceous conditions at GAMARI001 indicate naturally open herbaceous seepage bogs on the Georgia Fall Line. Naturally open seepage bogs had not previously been documented from either extreme southwest Georgia or the Fall Line Sand Hills of western Georgia.

Some of the creek systems with Atlantic White Cedar (*Chamaecyparis thyoides*) in the Fall Line Sand Hills of Georgia (Taylor, Talbot and Marion Counties) contain rare wetland plant species in their riparian zones. When powerlines cross these riparian areas they provide open space niches for seepage species and easy access for the discovery of noteworthy plants that are associated with Atlantic White Cedar habitats.

With few exceptions most of these rare seepage wetland plants are probably not moving along power line right-of-ways and colonizing new sites. All *Sarracenia* species have hydrophobic seeds and seem to be chiefly dispersed by floating locally within a site or moving downstream (Folkerts 1988; Sheridan 1996). Genera such as *Juncus* and *Drosera* and some members of the Cyperaceae have small, light seeds which potentially could become airborne and spread to appropriate habitat. The senior author has also observed an apparent case of *Drosera capillaris* and *Rhynchospora* species coming up from a seed bank at VADINW002 as well. Sites for colonization and germination may be provided when easements are mechanically cleared and soil lightly disturbed.

The senior author has also observed *Sarracenia flava* and *S. purpurea* persisting in low numbers in overgrown, wooded seepage habitats in Virginia. *Chelone cuthbertii*, *Platanthera blephariglottis*, and *Zigadenus glaberrimus* have flowered following clearing of woody vegetation from a site in Virginia (Sheridan, pers. obs.). These species may survive in either low numbers, lie dormant or in the seed banks in wooded seepage bogs provided there is periodic disturbance to stimulate flowering, fruiting and recruitment of seedlings. Powerlines constructed over such isolated populations would tend to provide the open conditions that would enhance these populations.

All or part of these factors may interact at any particular site to explain the presence of rare seepage wetland and pineland plant species on powerline rights-of-way.

## CONCLUSIONS AND RECOMMENDATIONS

Research needs to be completed on the recovery mechanisms for the rare plant taxa found in powerline easements in order to determine the limits in the range of tolerable disturbance types and frequencies. In addition more ecologically sound vegetation management strategies are needed to ensure the long term viability of these sites as both refugia for rare plant taxa and the significant biodiversity remnants of seepage bog communities and pineland groundcover types.

Powerline refugia might serve as a local measure of the biodiversity in regions where the surrounding natural vegetation has been highly altered or subjected to fire suppression and seepage bogs and pineland plants are now restricted to powerline easements.

Mechanical clearing of powerline easements should be continued to maintain the open space niches that favor rare herbaceous plants. Efforts to control or reduce any adverse side effects from mechanical clearing (soil erosion, sheet wash, rutting of seepage bogs, etc.) should be implemented. Effects of the application of herbicides on rare plant populations also needs to be studied. Other management strategies that delay mowing or clearing operations until flowering/fruiting are encouraged.

Future powerline routes in coastal Georgia, Maryland, and Virginia should consider seepage wetlands as prime routes. New lines may serve as a means of restoring and protecting valuable wetlands. Restoration of wetlands through powerline maintenance may be eligible for tradeable mitigation credits or cash.

Existing rights-of-way should be evaluated for rare plants and effective conservation measures considered. Rare plant location data should be restricted and not publicly available to prevent vandalism of sites. A public relations campaign should be initiated to educate the public about the valuable contribution utility companies have provided to maintain rare plant biodiversity.

When the senior author approached a local chapter of a national conservation agency in 1985 about acquiring or protecting a power line bog he was told, "Powerlines aren't natural areas". He had already come to realize, however, that indeed powerlines were substituting for natural areas in certain parts of the country and were worth protecting and investigating. In the last few years the Virginia Natural Heritage Program has realized the important role of powerlines as rare plant habitats and has begun investigating such areas (Springston 1995). We heartily endorse this effort and look forward to a bright future between power companies and environmental groups ensuring both preservation of our natural resources and reliable energy supplies.

## ACKNOWLEDGEMENTS

Thanks to Mark and Carol Strong and Robert Wright for the use of their specimens, as well as their friendship and kindness over the years. James and Betty Scholl have been invaluable in their support and accommodation of our work in southern Virginia and their son Bill has been ally and a true friend through our shared efforts. Dr. Alton Harvill and the late Barbara Harvill funded part of the Virginia fieldwork and we thank them as well. We also thank the landowners who were kind enough to give us permission to botanize their property. Final appreciations to Ted Bradley for his assistance and friendship and to Chris Ludwig for informing the senior author of VAGREE018 and VASUSS004. Thanks to the reviewers for their comments and to anyone else who may have helped us in this work.

## REFERENCES

Bridges, E.L. and S.L. Orzell. 1989. Longleaf pine communities of the West Gulf coastal plain. Natural Areas Journal, 9(4): 246–263.

Core, E. 1970. The Botanical exploration of the southern Appalachians. In: The Distributional History of the Biota of the Southern Appalachians, Part II: Flora. Research Division Monograph 2, F.C. Holt, ed. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. pp. 61–65.

Fenwick, G.H. and D.D. Boone. 1984. The peatlands of Maryland. In: Threatened and Endangered Plants and Animals of Maryland. A.W. Norden, D.C. Forester, and G.H. Fenwick, eds. Maryland Natural Heritage Program, Spec. Publ. 84-1. Maryland Department of Natural Resources, Annapolis, Maryland. pp. 139–159.

Fernald, M.L. 1937. Local plants of the inner coastal plain of southeastern Virginia. Rhodora, 39: 321–366.

Fernald, M.L. 1939. Last survivors in the flora of tidewater Virginia. Rhodora, 41: 465–574.

Fernald, M.L. 1940. A century of additions to the flora of Virginia. Rhodora, 42: 355–521.

Folkerts, G. 1982. The Gulf Coast pitcher plant bogs. American Scientist, 70: 260–267.

Folkerts, G. 1988. Dispersal types in the flora of pitcher plant habitats in the southeastern U.S. ASB Bulletin, 35(2): 77–78.

Folkerts, G. 1991. A preliminary classification of pitcher plant habitats in the southeastern United States. Journal of the Alabama Academy of Science, 62(4): 199–225.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. In: The Longleaf Pine Ecosystem: Ecology, Restoration and Management. S.H. Hermann, ed. Proceedings of the Tall Timbers Fire Ecology Conference, No. 18. Tall Timbers Research Station, Tallahasse, Florida. pp. 17–43.

Frost, C.C. 1995. Presettlement fire regimes in southeastern marshes, peatlands, and swamps. In: Fire in Wetlands: A Management Perspective. I.C. Susan and R.T. Engstrom, eds. Proceedings of the Tall Timbers Fire Ecology Conference, No. 19. Tall Timbers Research Station, Tallahassee, Florida. pp. 39–60.

Frost, C.C. and L.J. Musselman. 1987. History and vegetation of the Blackwater Ecologic Preserve. Castanea, 52(1): 16–46.

Georgia Department of Natural Resources. 1991. Georgia Natural Heritage Program.

Georgia Department of Natural Resources. 1993. Special plants of Georgia, interim version. 11 pp.

Hardin, D.E. and D.L. White. 1989. Rare vascular plant taxa associated with wiregrass in the southeastern United States. Natural Areas Journal, 9(4): 234–245.

Harper, R. 1904a. *Sarracenia flava* in Virginia. Torreya, 4(8): 123.

Harper, R. 1904b. Explorations in the coastal plain of Georgia during the season of 1902. Bulletin Torrey Botanical Club, 31: 9–27.

Harper, R. 1905a. Phytogeographical explorations in the coastal plain of Georgia in 1903. Bulletin Torrey Botanical Club, 32: 141–171.

Harper, R. 1905b. Phytogeographical explorations in the coastal plain of Georgia in 1904. Bulletin Torrey Botanical Club, 32: 451–467.

Harper, R. 1907. A midsummer journey through the coastal plain of the Carolinas and Virginia. Bulletin Torrey Botanical Club, 34: 351–377.

Kartesz, J.T. 1994. A Synonomized Checklist of the Vascular Flora of the United States, Canada, and Greenland. Volume 1, 2nd edn. Timber Press, Portland, Oregon. 622 pp.

Ludwig, J.C. 1997. Natural heritage resources of Virginia: rare vascular plants. Natural Heritage Technical Report 97-1. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. 34 pp.

Maryland Natural Heritage Program. 1994. Rare, threatened and endangered plants of Maryland. Department of Natural Resources, Annapolis, Maryland. 24 pp.

McAtee, W.L. 1918. A sketch of the natural history of the District of Columbia together with an indexed edition of the U.S. Geological Survey's 1917 map of Washington and vicinity. Bulletin of the Biological Society of Washington, No. 1, 142 pp.

Patrick, T.S., J.R. Allison, and G.A. Krakow. 1995. Protected plants of Georgia. Georgia Department of Natural Resources, Social Circle, Georgia. 246 pp.

Pederson, F.C. 1941a. A forest fire prevention and suppression program for Virginia. Part I. Virginia Journal of Science, 2: 265–269.

Pederson, F.C. 1941b. A forest fire prevention and suppression program for Virginia. Part II. Virginia Journal of Science, 2: 53–58.

Rock, H. 1957. A revision of the vernal species of *Helenium*. Rhodora, 59: 206.

Rudis, V.A. and T.V. Skinner. 1991. Fire's importance in south central U.S. forests: distribution of fire evidence. In: Fire and the environment: ecological and cultural perspectives. S.C. Nodvin and T.A. Waldrop, eds. General Technical Report SE-69. Southeastern Forest Experiment Station, Asheville, North Carolina. pp. 240–251.

Sheridan, P. 1991. Noteworthy collections. Castanea, 56(1): 71–72.

Sheridan, P. 1996. The Virginia pitcher plant bogs. IV. Seed dispersal and dissemination in a Suffolk county population of *Sarracenia flava*. Virginia Journal of Science, 47(2): 105.

Sipple, W. and W. Klockner. 1984. Uncommon wetlands in the coastal plain of Maryland. In: Threatened and Endangered Plants and Animals of Maryland. A.W. Norden, D.C. Forester, and G.H. Fenwick, eds. Maryland Natural Heritage Program, Spec. Publ. 84-1. Maryland Department of Natural Resources, Annapolis, Maryland. pp. 111–137.

Strong, M. and P. Sheridan. 1991. *Juncus caesariensis* Coville (Juncaceae) in Virginia peat bogs. Castanea, 56(1): 65–69.

Springston, Rex. 1995. Along power lines, nature surges. Richmond Times Dispatch, (11.1.95): B6

Waldrop, T.A., D.L. White and S.M. Jones. 1992. Fire regime for pine-grassland communities in the southeastern United States. Forest Ecology and Management, 47: 195–210.

Walker, J. 1993. Rare vascular plant taxa associated with the longleaf pine ecosystems: patterns in taxonomy and ecology. Proceedings of the 18th Tall Timbers Fire Ecology Conference 18: 105–125.

Ware, D. and T. Wieboldt. 1981. Rediscovery of *Juncus caesariensis* Coville in Virginia. Jeffersonia, 12(2): 6–10.

## BIOGRAPHICAL SKETCHES

***Philip M. Sheridan***

*Meadowview Biological Research Station, 8390 Fredericksburg Turnpike, Woodford, VA 22580, USA; Dept. of Biology, Virginia Commonwealth University, 816 Park Avenue, Richmond, VA 23284, USA*

Phil Sheridan is director of Meadowview Biological Research Station in Caroline County, Virginia and specializes in the study and conservation of wetland plants. He is a graduate of Virginia Commonwealth University in Richmond, Virginia with both a Bachelor and Master of Science degree in Biology and is a Biology Instructor at that University.

***Steve Orzell***

*OLA DET 1, 347 OG/CEVN, 29 South Blvd., Avon Park Air Force Range, FL 33825-5700, USA*

Steve Orzell is the Staff Ecologist/Botanist for Avon Park Air Force Range in south-central Florida. He has over 20 years experience in natural area inventories and rare plant surveys in the midwest and southeastern United States.

***Edwin Bridges***

*7752 Holly Tree Place, N.W., Bremerton, WA 98312, USA*

Edwin Bridges is the former Curator of Fairchild Tropical Garden and has over 20 years of research in plant taxonomy and ecology. He is the recognized authority on the field identification, classification, and ecology of the sedges and grasses of Florida and is editor of the monocot family treatments for the forthcoming *Flora of Florida*.

# Part X
# Erosion Control

# Comparative Evaluation of Erosion and Water Temperature in Small Streams Located in Powerline Rights-of-Way and in the Upstream Undisturbed Habitat

**Yves Garant, Jean Domingue, and François Gauthier**

There are over 8,000 riparian vegetation strips within Hydro-Québec's utility network, maintained to preserve the natural characteristics of small streams. In a clearcut landscape, riparian strips prevent soil erosion and a rise of temperature in small streams. Rights-of-way (ROWs) located in a forested landscape may present a different situation because the clearcut area is significantly smaller than in a conventional logging operation. The object of our study was to test the hypothesis that erosion in small streams located in ROWs and protected by a low vegetation cover is comparable to erosion in upstream segments in the natural forest (NAT). We also tested the hypothesis that temperature variations in stream segments located in ROWs are similar to variations in upstream forested segments. Erosion was measured in 36 streams crossing ROWs. Erosion type and severity were classified using a quantitative scale and a compounded erosion index was derived for comparison purposes. Erosion indices were not statistically different between ROW and NAT sections. Scouring was common in both sections and affected about 36% of the stream bank length. Water temperature was measured in 33 streams with a riparian strip of low vegetation (≤1 m). Water temperature in upstream segments was comparable to temperature measured in ROWs. Stream temperature, when leaving the ROWs, was <18°C in 90% of the streams. Temperature variations in ROWs (1.4°C/100 m) were not statistically different from variations in upstream segments (1.5°C/100 m).

*Keywords*: Buffer zones, erosion, gullying, powerline, right-of-way, riparian strips, scouring, streams, temperature

## INTRODUCTION AND OBJECTIVES

The Hydro-Québec electrical network includes 164,000 ha of powerline rights-of-way (ROWs). Within the network, there are approximately 8,000 buffer zones, the majority being riparian vegetation strips maintained to preserve the natural characteristics of small streams. These buffer zones require particular maintenance measures such as hand cutting of vegetation.

In a clearcut landscape, the environmental role played by riparian strips is the prevention of soil erosion and increases of the sediment loads and a rise of temperature in small streams and rivers (Brown and Krygier 1970, Budd et al. 1987, Karr and Schlosser 1978). Rights-of-way located in a forested landscape, such as those found on the North Shore of the Saint-Lawrence River (Québec), may present a different situation because the clearcut areas for ROWs are significantly smaller than the areas deforested during a conventional logging operation. Recent literature reviews indicate that empirical data are limited on these specific topics (soil erosion and stream temperature in ROWs) and that most studies were conducted in large clearcuts (Gauthier 1992, Naturam Environnement 1994). The purpose of our study was to characterize soil erosion and temperature in small streams located in powerline ROWs. More specifically, we tested the following hypotheses:

1. Erosion in small streams located in ROWs and protected by a riparian vegetation strip is comparable to erosion in upstream segments in the adjacent natural forest;

2. Temperature variations in stream segments located in ROWs, protected by a low vegetation cover (≤1 m), are similar to variations measured upstream in the adjacent natural forest.

## METHODS

### Erosion

The study was carried out during the summer of 1995 on the North Shore of the Saint-Lawrence River, approximately 200 km east of Québec City, in powerline ROWs located between Tadoussac and Baie-Comeau (Fig. 1). We selected 32 small streams with 10 m buffer zones and four streams with 30 m buffer zones. Streams were divided into two sections: a 100 m natural upstream segment (referred to as NAT) and a 100 m ROW segment. Erosion was determined on both stream banks for a maximum length of 200 m in each section. Underground sections of the stream were subtracted from the total length. Erosion type and severity were classified according to a quantitative matrix (Table 1). A set of measures were taken on each stream to characterize the substrate and the flow facies.

**Table 1. Quantitative values used to characterize erosion in small streams**

| Severity | Erosion type | | |
|---|---|---|---|
| | Slipping | Scouring | Gullying |
| 1 (low) | 5 | 2 | 1 |
| 2 (moderate) | 10 | 4 | 2 |
| 3 (high) | 25 | 10 | 5 |

An erosion index was calculated for each stream to facilitate comparison between the NAT and ROW sections of a given stream:

$$E = \sum(P_{ij} \times C_{ij})$$

where $E$ is the compounded erosion index; $P$ is the proportion of stream bank with severity $i$ and type $j$; and $C$ is the erosion value for severity $i$ and type $j$ (from Table 1).

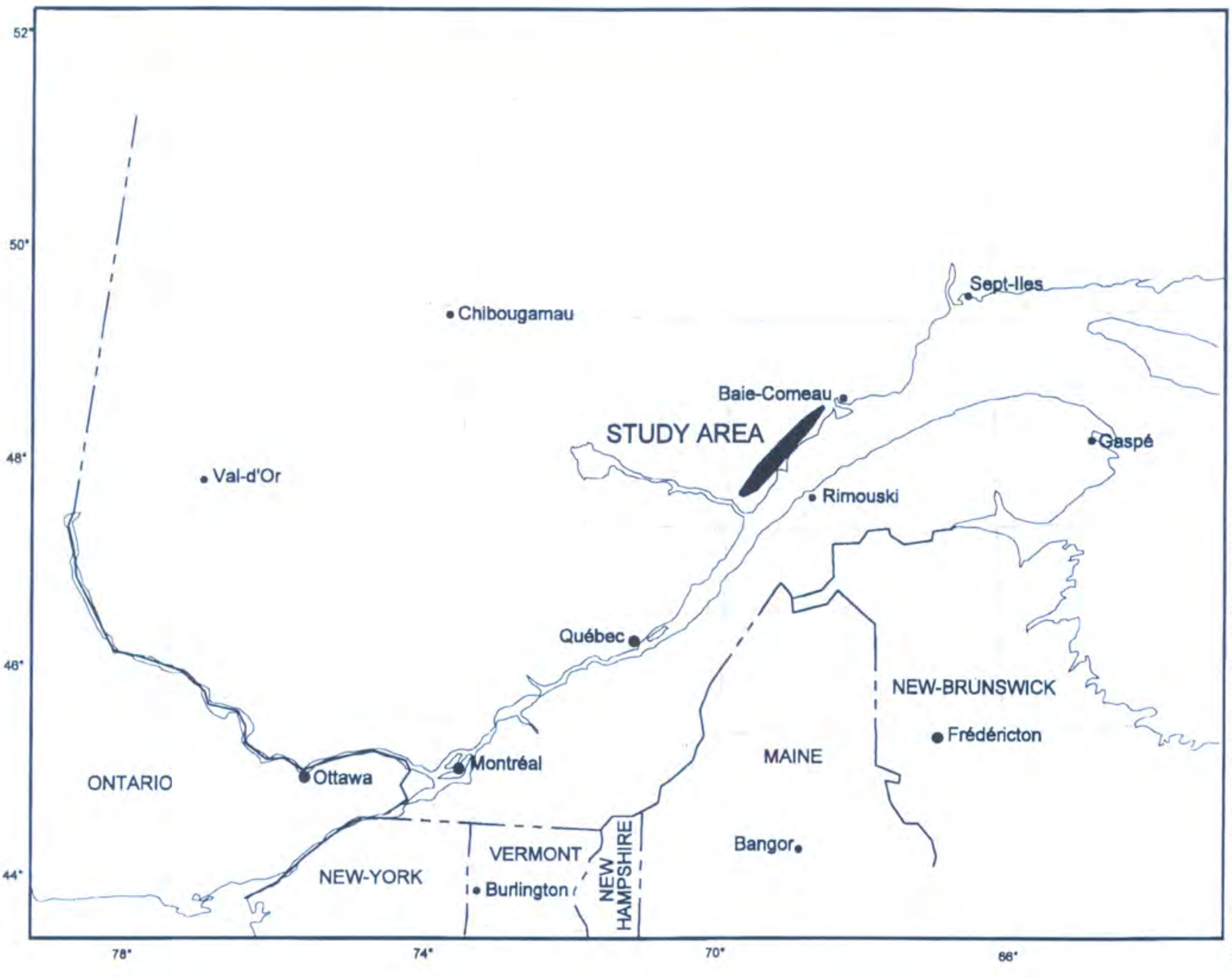



Fig. 1. Location map of the study area.

## Stream temperature

A preliminary sample of 122 streams located in power-line ROWs was initially selected by photogrammetry. Each stream was then examined according to several criteria that could potentially influence stream temperature (Table 2) and 33 streams were selected following a field validation.

Water temperature (±0.1°C) was recorded at four sites in 33 streams with a riparian strip of low vegetation (≤1 m) located in ROWs: 50 m upstream (A), at the upstream (B) and downstream (C) forest-ROW borders and 50 m downstream (Fig. 2). Temperatures were recorded with electronic thermometers (Hanna Instruments, models 8053 and 8314) during sunny days in July 1995. Temperature variations were standardized (°C/100 m of stream) for comparison purposes. Vegetation cover and sociability were each classified into one of the categories presented in Table 3. Other stream characteristics measured in ROWs were length, width, speed, depth and type of substrate.

## Statistical analyses

Frequency distribution of erosion indices were compared between ROW and NAT sections by a Kolmogorov–Smirnov test and a *t*-test for matched pairs (Daniel 1978). A Chi-square test was used to compare frequencies of a given type of erosion between ROW

**Table 2. Criteria used in selecting small streams**

| Criteria |
|---|
| Riparian strip composed exclusively of low vegetation (≤ 1 m) |
| No upstream beaver dam within 50 m |
| Comparable slope in ROW and NAT stream segments |
| No tributary within 50 m of the ROW |
| Stream width < 10 m |
| Stream perpendicular to ROW |
| No ROW within 100 m of upstream segment |

**Table 3. Cover and sociability classes used to describe vegetation in riparian strips**

| Cover | | Sociability | |
|---|---|---|---|
| Class | Description | Class | Description |
| † | isolated | 1 | isolated |
| 1 | 1–5% | 2 | small but dense clumps |
| 2 | 6–25% | 3 | small patches |
| 3 | 26–50% | 4 | small colonies |
| 4 | 51–75% | 5 | large colonies |
| 5 | 76–100% | | |

Source: Barbour et al. (1980).

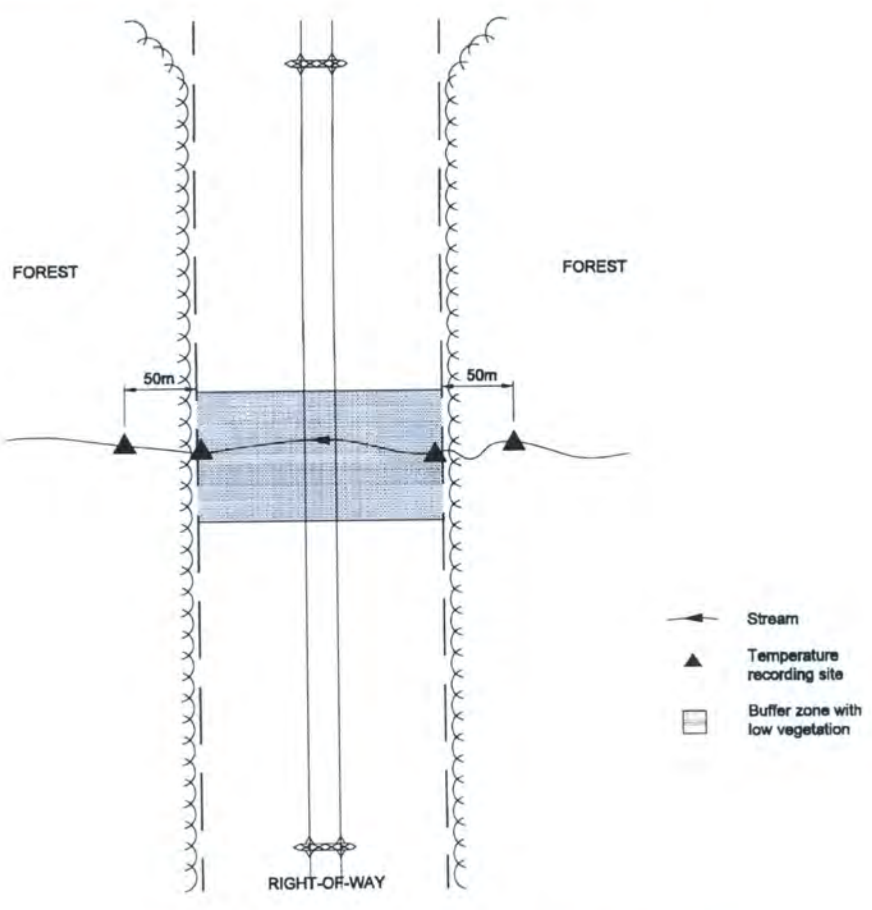



Fig. 2. Schematic of stream temperature recording sites.

and NAT sections. Temperature variations were compared with a $t$-test for matched pairs (Daniel 1978).

Variables were log-transformed when normality was not respected (Sokal and Rohlf 1981). Regional temperature variations were compared by Mann–Whitney U-test (Daniel 1978). We considered that temperature was constant when variation was ≤0.2°C/100 m. Statistical analyses were executed with SPSS (Statistical Package for the Social Sciences) software version 6.0 for Windows (Norusis 1993). We used an alpha level of 0.05 to detect significant differences.

## RESULTS AND DISCUSSION

### Erosion

Mean (± standard deviation) stream width was 3.2 m (± 2.5 m) with an average depth of 31 cm (± 28 cm) (Table 4). Underground portions accounted for less than 10% of stream length. Signs of erosion were observed in 92% and 94% of streams in the NAT and ROW sections, respectively. In both ROW and NAT sections, low and moderate levels of scouring were the most common types of erosion (Table 5). Frequency of occurrence was approximately 90% for scouring and 11% for gullying. Land slipping was observed significantly more frequently in ROW segments (35%) than in upstream NAT segments (11%) (Chi-square test = 10.47, $P < 0.05$). However, it occurred in 1% or less of the stream banks in both sections.

Compounded erosion indices were not statistically different between ROW and NAT stream segments (Wilcoxon matched-pairs test, $P = 0.63$) (Table 5). The typical stream was eroded by scouring at 36% of its banks and at 1% of its banks by gullying and slipping, regardless of its location. Three streams running on bedrock showed no sign of erosion. Severe erosion was observed in 23 streams but this was restricted to very narrow strips of the stream bank.

A large number of factors can affect the rate of bank erosion including stream flow pattern, soil moisture, bed materials, vegetation type and cover (Gordon, McMahon and Finlayson 1993). Compounded erosion indices were often variable within the NAT and ROW sections of the same stream, but no clear erosion pattern was observed. Most importantly, vegetation along stream banks holds the soil in place and reduces sediment transport to the aquatic environment. Since shrubby vegetation was maintained along streams in ROWs, this has likely provided a sufficient protection from erosion.

### Stream temperature

Most of the streams (85%) studied for temperature variation were small with an average width of 2 m (± 1.1 m) (range: 0.3–5.5 m) and an average depth of 22 cm (± 15 cm) (Table 6). Morphological and thermal characteristics of these streams were highly variable, but likely reflected the range of variations for small streams on the North Shore of the Saint-Lawrence River.

The vegetation cover stretching above streams ranged from 5 to 95% for a median of 18%. In our sample, at 42% of the streams, herbs, grasses and low shrubs formed less than a 10% cover, while 26% of the streams had a vegetation cover ranging between 10 and 50%. Vegetation cover was greater than 50% in one out of three cases.

Water temperature in upstream segments was highly variable with values ranging from 4.5 to 22.9°C (12.2 ± 4.0°C). Temperature rose in 55% of the upstream segments, 39% of them had a stable temperature (variation ≤ 0.2°C/100 m), and only 6.1% cooled.

**Table 4. Characteristics of streams in the natural upstream habitat**

| Variable | $n$ | Mean | S.D. | Min. | Max. |
|---|---|---|---|---|---|
| Bank length surveyed (m) | 36 | 191 | 26 | 88 | 200 |
| Stream width (m) | 36 | 3.20 | 2.50 | 0.30 | 10.70 |
| Depth (cm) | 36 | 31 | 28 | 4 | 120 |

S.D. = standard deviation.

**Table 5. Relative importance of each type of erosion measured in right-of-way (ROW) and upstream natural habitat (NAT)**

| Erosion type | ROW | NAT |
|---|---|---|
| Scouring | | |
| Frequency (%) | 88.5 | 91.7 |
| Percent stream bank | 35.1 | 37.4 |
| Gullying | | |
| Frequency (%) | 11.5 | 11.1 |
| Percent stream bank | 0.1 | 0.2 |
| Slipping | | |
| Frequency (%) | 34.6 | 11.1 |
| Percent stream bank | 1.0 | 0.3 |
| No erosion | | |
| Percent stream bank | 63.8 | 62.1 |
| Compounded erosion index | 1.47 | 1.51 |

**Table 6. Physical characteristics of streams, air temperature and vegetation cover at sampling sites**

| Variable | $n$ | Mean | S.D. | Min. | Max. |
|---|---|---|---|---|---|
| Length (m) | 33 | 205 | 100 | 95 | 532 |
| Width (m) | 33 | 1.2 | 1.1 | 0.3 | 5.5 |
| Depth (cm) | 33 | 22 | 15 | 8 | 80 |
| Temperature (°C) | 33 | 13.0 | 3.4 | 8.5 | 22.7 |
| Speed (m/s) | 26 | 0.26 | 0.18 | 0.03 | 0.67 |
| Air temperature (°C) | 33 | 26.7 | 3.7 | 21.0 | 32.3 |
| Cover (%) | 31 | 32 | 34 | 0 | 95 |

S.D. = standard deviation.

Temperature variation in ROWs (1.4°C/100 m) was not statistically different than the variation recorded in upstream segments (1.5°C/100 m). The average air temperature in ROWs was 26°C.

Stream temperature when leaving the ROW ranged between 9.7 and 22.5°C (mean: 14.2 ± 3.4°C); temperature was ≤ 18°C in 88% of the streams. Temperature variation in ROW section was ≤ 2.0°C in 85% of streams; only 5 streams showed a rise of temperature between 2.2°C and 4.4°C. However, the temperature of these streams, 50 m downstream, remained stable or decreased slightly. A similar situation was observed by Burton and Likens (1973), who reported that small streams have the capacity to recover quickly and return to their initial temperature after a rise in an open area (e.g., clearcut). Furthermore, it is worth mentioning that Montgomery (1976) measured daily temperature variation of 4°C in undisturbed streams, but this variation increased to 10°C or more when all shade along stream was removed.

These results support the hypothesis that small stream crossing powerline ROWs in the North Shore region do not exhibit a significant rise in temperature when compared to their upstream natural counterparts. Temperature variations were usually small and negligible for fishes, even for sensitive species such as salmonids that can tolerate temperature of 20–21°C (C.C.M.R.E. 1987). Water temperature usually increases in the downstream direction, to a point where water approaches an equilibrium with the air temperature (Gordon McMahon and Finlayson 1993). Direct solar radiation is the principal source of energy for warming streams (Brown and Krygier 1970). In this experiment, a vegetation cover composed of herbs, grasses and low shrubs appeared to prevent an excessive rise of temperature in small streams. Canopy density, a measure of shading effectiveness, can be correlated with stream temperatures (Budd, Cohen, Saunders, and Steiner 1987). We did not, however, measure any significant correlation between percent cover and temperature variation in the ROW stream segments ($P > 0.05$) in this study, even when controlling for temperature variation in upstream segments.

Cover is only one of many factors that can directly affect water temperature. Groundwater seepage, stream depth, wind, and geographical location can also affect water temperature. Duplication of this experiment in the same region and in other regions located further south where greater natural temperature variation are expected in small streams, should allow us to acquire more knowledge on small stream thermodynamics in ROWs.

## REFERENCES


Barbour, M.G., J.H. Burk, and W.D. Pitts. 1980. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company Inc., Menlo Park, California. 604 pp.

Brown, G.W. and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research, 6 (4): 1133–1139.

Budd, W.W., P.L. Cohen, P.R. Saunders, and F.R. Steiner. 1987. Stream corridor management in the Pacific Northwest: 1. Determination of stream-corridor width. Environmental Management, 11: 587–597.

Burton, T.M. and G.E. Likens. 1973. The effect of strip cutting on stream temperatures in the Hubbard Brook Experimental Forest, New Hampshire. Bioscience, 23: 433–435.

C.C.M.R.E. 1987. Canadian water quality guidelines. Canadian Council of Resources and Environment Ministers.

Daniel, W.W. 1978. Applied Nonparametric Statistics. Houghton Mifflin Company, Boston, Massachusetts. 503 pp.

Gauthier, F. 1992. Pertinence du maintien des écrans de végétation dans les emprises de lignes de transport et de répartition. Hydro-Québec, 26 pp.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1993. Stream Hydrobiology: An Introduction for Ecologists. John Wiley and Sons, Chichester, U.K. 526 pp.

Karr, J.R. and I. Schlosser. 1978. Water resources and the land–water interface. Science, 201: 229–234.

Montgomery, J.M. 1976. Forest harvest, residue treatment, reforestation and protection of water quality. Prepared for US Environmental Protection Agency. National Technical Information Service, Virginia. 273 pp.

Naturam Environnement. 1995. Le rôle écologique des écrans de végétation dans les emprises de lignes de transport et de répartition d'énergie. Hydro-Québec. 18 pp.

Norusis, M.J. 1993. SPSS for Windows. Base System User's Guide. Release 6.0. SPSS Inc, Chicago, 828 pp.

Sokal, R.R. and F.J. Rohlf. 1984. Biometry, 2nd edn. W.H. Freeman and Company. San Francisco, California. 776 pp.


---

### *BIOGRAPHICAL SKETCHES*


***Yves Garant***

*Naturam Environnement, 31 Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*


Yves Garant holds an M.Sc. degree in Renewable Resources from McGill University and has been working as a wildlife consultant since 1986. He has conducted several research projects in rights-of-way management for Hydro-Québec. His main research interests are ungulate and furbearer ecology and management.


***Jean Domingue***

*Naturam Environnement, 31 Marquette, Baie-Comeau, Québec, Canada, G4Z 1K4*


Jean Domingue is president and director of Naturam Environnement Inc. since 1985, a consulting firm specialized in Biology, Forestry, and Environment. His areas of interest are diverse and include application of high-technology in resource management, vegetation maintenance in utility rights-of-way, industrial monitoring and impact assessments.

*François Gauthier*

*Hydro-Québec, Direction principale Communication et Environnement, 75 Boulevard René-Lévesque Ouest, 16e étage, Montréal, Québec, Canada, H2Z 1A4*

François Gauthier obtained a B.Sc. degree in Forestry in 1980 and an M.Sc. degree in Environment in 1992. He has been working for Hydro-Québec for 15 years in the vegetation control field, more specifically on the environmental aspect of this activity. He has conducted many research projects and studies in this area and has developed an integrated approach to vegetation maintenance.

# Flexible Channel Liner Study at the TxDOT/TTI Hydraulics and Erosion Control Field Laboratory

**Jett A. McFalls**

Texas Transportation Institute's (TTI) Environmental Management Program is currently operating a full-scale, outdoor evaluation facility for the performance testing of selected erosion control materials. The overall purpose of the facility is to produce and maintain a defensible "Approved Products List" to be used on all Texas Department Of Transportation (TxDOT) construction and maintenance activities. TTI's goal was to construct a facility which would simulate the highway environment to the greatest degree possible while providing the capability of collecting data on the critical performance factors of roll-type erosion control products. To achieve this goal the Hydraulics and Erosion Control Field Laboratory was constructed. The facility has the capability to conduct performance tests on erosion control products for embankment protection and for flexible channel liners.

*Keywords*: Erosion control, sediment control, liners, roadside channels, sediment loss, vegetation establishment, storm water management

## INTRODUCTION

The erosion control industry and the Federal Highway Administration (FHWA) recognize a wide variety of generic materials that may be used as erosion control protection. Erosion-control blankets that met the Texas Department of Transportation's standard specifications for the past twenty years consisted of two products. Technically, products that did not meet the material-based specification were excluded from the specification and bidding process. In response to this practice, TxDOT searched for alternatives that would provide a fair system of selecting and specifying erosion control products based upon their performance. TxDOT and TTI initiated a cooperative research study in 1989 to help further this initiative.

Once TTI determined TxDOT's needs and reviewed the current state-of-practice in erosion control, they recommended evaluating erosion control materials based upon their field performance rather than traditional laboratory testing. Since the textile industry developed erosion-control blankets and mats, a variety of laboratory tests were developed to describe physical properties such as tensile and shear strength, heat resistance, etc. However, these tests do not adequately describe or test field performance. Laboratory tests and field observations suggest there is great variation in strength, durability, soil–blanket interaction, and vegetation response between generic material classifications and between manufactured brands of similar materials. Soil–fabric interaction, vegetation establishment, and installation methods are critical factors to consider in determining field performance characteristics.

TTI developed evaluation methodologies for the Department's most pressing needs: erosion-control blankets in varying slope applications and flexible channel liners in varying shear stresses. A state-of-the-art facility was designed and constructed during a two year period to accommodate these application areas and more. Today, the facility is a nine hectare site that includes approximately three hundred linear meters by six vertical meters of fill embankment, ten at-grade channels, two reservoirs, pumping stations, rainfall simulators, and various instrumentation.

Since 1991, an annual evaluation of erosion control products have been studied at the Hydraulics and Erosion Control Laboratory. Data on specific field performance characteristics such as apparent vegetation coverage and sediment loss are collected and analyzed. Vegetation coverage is collected and analyzed by a video/image capture, an interactive, color analysis process. Artificial rainfall simulations provide the researchers with sediment loss ratios. TxDOT uses the data to support their *Annual List of Approved Materials* and develop standard installation detail sheets as construction document inserts. Private industry, TxDOT, and TTI cooperatively work to further this important area of environmental research and development. This cooperation led to a timely and fair program through which manufacturers' erosion control related materials are evaluated for use in TxDOT's construction and maintenance activities. The research objectives set forth include the following:

- Determine the acceptable performance level in fostering the establishment of vegetative cover and sediment retention for slope and channel application areas within highway rights-of-way.

## FLEXIBLE CHANNEL LINER STUDY

The flexible channel liner testing facility consists of ten, at-grade channels (six with a 7% centerline gradient, and four with a 3% centerline gradient). Each open channel has a trapezoidal cross section that includes a 0.30 m (1 ft) flat bottom, 1:1 side slopes, and a typical 0.91 m (3 ft) depth beginning 4.5 m (15 ft) downstream of the channel release gate. The total length of each test channel is 26 m (85 ft). Water for the channels is supplied by an industrial grade, high-volume, low-head, axial-flow, pump capable of producing over 136,260 liters per minute (36,000 gallons per minute).

Channel treatment begins with the installation of the flexible channel liner and the application of the TxDOT rural area, warm-season seed mixture for the District. Fertilizer is applied integrally with the seed mixture at the rate of 102.15 kg per 0.405 ha (225 lbs/acre). Experimental control consists of one channel receiving the same vegetative treatment with no erosion-control material in place. Treatment plots are analyzed for their sediment retention performances (channel deformation) and apparent vegetative density coverage with respect to shear stress capacity range.

Sediment retention criteria are as follows:

- Acceptable flexible channel liners should reduce the sediment loss and channel degradation from the protected treatment area significantly greater than from bare ground (Control).
- Flexible channel liners should effectively protect the seed bed from a short duration flow that produces less than 95.76 Pa (2 lbs/ft$^2$)shear stress on the channel bottom within the first 90 days after installation.

Vegetation density coverage criteria are as follows:

- Acceptable flexible channel liners should promote significantly greater vegetative cover on the protected treatment area as compared to bare ground (Control).
- Acceptable flexible channel liners should promote a vegetative cover within the first six months after installation by protecting the seed bed from the impacts of shear stress from water flow and rain splash from raindrop velocity.
- In cohesive soils (clay), vegetation density should reach and maintain a minimum coverage of 70% during the first six months after installation.

### Shear stress data

In straight line channels, the maximum tractive force occurs on the bottom and near the center of the channel. The force generated at this point is a function of $Y$, the unit weight of water; $d$, the depth of flow; and $S$, the average slope of the channel bottom (energy gradient). This relationship allows one to estimate the maximum permissible tractive force with a single calculation as follows:

$$\tau_d = YdS$$

### Manning's *n* value for flexible channel liner research

For the flexible channel liner study, the researchers determined Manning's $n$ value to simulate flows of equal shear stress upon the liner's bottom. To determine Manning's $n$ or roughness coefficient for each flexible channel liner, researchers used an indoor flume facility located at the College of Ocean Engineering, Texas A&M University. Physical dimensions of the box-shaped flume are approximately 0.46 m (18 in) in width, 1.22 m (4 ft) in height, and 21 m (70 ft) in length. The energy gradient is 2% longitudinally along the flume bottom. Researchers view the flows through the plexiglass sides of the flume.

The researchers attached the product to the plywood flume bottom with carriage bolts and washers placed 0.46 m (18 in) on center. At a predetermined rate of flow ($Q$), the researchers simulated a series of flows to collect velocity and depth measurements. Using a digital flow meter, the researchers recorded velocity at six different location in a single cross-section, to calculate the average velocity during uniform flow. The researchers used a point-gauge instrument to calculate depth of flow. Flow duration was for twenty minutes with data recorded every four minutes. Manning's $n$ may be determined since rate of flow ($Q$), channel geometry and slope, measured resultant mean water velocity and depth of flow, are known. With this data, the research team figured a minimum, normal, and maximum Manning's $n$ for each product prior to any flow simulations in the field.

### Channel degradation (sediment) data for flexible channel liners

Following installation, each product is given a 90-day resting period to promote the initial growth of vegetation

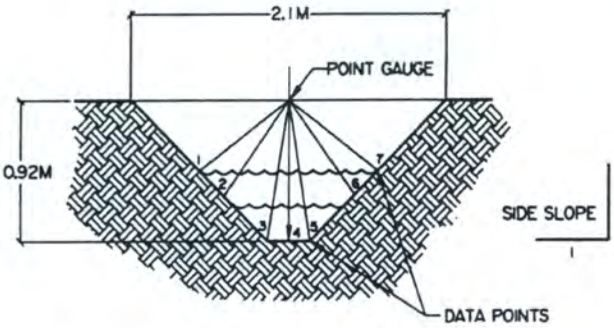



Fig. 1. Channel cross section showing locations of measurements.

prior to initiating a series of increasing, shear-stress flows. After the 90-day rest period, a series of simulated flows begin. Prior to each flow, channels are pre-wetted to moisten the channel surface. Based upon the determined Manning's *n*, and the known geometry of the channel, the depth of the water is controlled to initiate a series of increasing flows on 48 Pa (1 lb/ft$^2$) increments. Each flow is repeated twice, each flow being twenty (20) minutes after uniform flow has been achieved. During the test flows, measurements are taken approximately every two minutes to determine the water velocity. Further, data is collected regarding product movement (loss of intimate contact with the soil). To determine channel deformation, cross sections are taken before and after each test flow. Using a point gauge at four different stations along the channel, seven readings are taken at each station as shown in Fig. 1. This procedure enables the researchers to quantify sediment retention and sediment bed load migration.

The average soil displacement exhibited within the channel is compared to the adopted maximum soil displacement standard to determine acceptance or rejection. All channels are also sampled to determine the growth of vegetation. Each channel is initially sampled at the end of the 90-day resting period for vegetation production. The final density sample is normally taken during November. The vegetation density achieved within the channel by the final sampling is compared to the adopted minimum vegetation density standard to determine acceptance or rejection.

## Shear stress (material performance) data for flexible channel liners

Before and after flow simulation, researchers visually inspected each treatment channel for any damage or undermining of the material. Significant rips, tears, pulling away at the seams or loss of material, etc., were recorded on a channel diagram and photographed. Since the researchers incrementally increase the shear stresses placed upon the flexible channel liners, these visual inspections help to determine if the liner should receive the next level of shear stress.

If a flexible liner has reached its maximum permissible tractive force capability, it has reached its "failure" point. "Failure" in this context refers to the amount of bare ground exposed due to the failure of the material to withstand the shear stresses generated upon them. One obvious failure point is the material physically pulls away from the surface and is transported downstream, thereby no longer providing protection to the channel surface. Minor migration of material components within the flexible channel liner, such as excelsior or straw materials, would not constitute a failure as described here. No repairs were made to the flexible channel liners when damage resulted from a simulated flow event.

## CONCLUSIONS AND TEST RESULTS

The research work accomplished at TTI continues the Federal Highway Administration's work cited in the FHWA Hydraulic Engineering Circular 15. While HEC 15 establishes that the maximum tractive force occurs at the bottom center of the channel floor (point 4 in Fig. 2), the TTI sediment loss data does not support this as the location of the maximum amount of soil deformation or movement. The location which actually exhibit the most soil loss is at points 3 and 5. Furthermore, the data also indicates that point 4 actually exhibits the least amount of soil deformation in 75% of the shear stress test flows performed. This seems to indicate that shear stress in not necessarily related to soil displacement. It seems to suggest that the flow turbulence at these edges is possibly more significant than the shear stress.

Failure appeared to be equally due to material failure as well as erosion failure. While most of the material damage seemed to occur early during the twenty minute test flows, erosion occurred throughout the entire twenty minute tests. Very little material damage took place at staple points even though some of the materials had a tenancy to float. Stapling pattern did not seem to affect the erosion. However, the more staples, the less material damage.

In HEC 15, the maximum recommended shear stress values in an unvegetated condition for flexible channel liners range from 7.18 to 95.76 Pa (0.15 to 2 lbs/ft$^2$). For

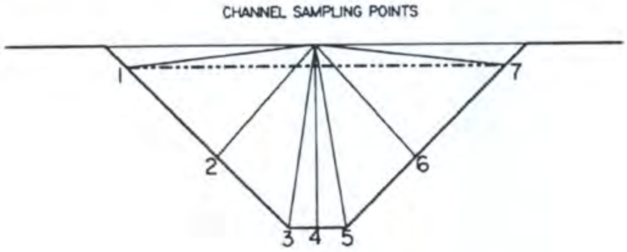



Fig. 2. Typical channel configuration.

**Table 1. Summary of data. Class 2 — 1996 Flexible Channel Liner Performance Test Results**

| Conditions | 0–96 Pa (2 lbs/ft$^2$) | | 0–192 Pa (4 lbs/ft$^2$) | | 0–287 Pa (6 lbs/ft$^2$) | | 0–383 Pa (8 lbs/ft$^2$) | |
|---|---|---|---|---|---|---|---|---|
| Minimum standards | Sediment (cm of channel deformation) | Density (% cover final round) | Sediment (cm of channel deformation) | Density (% cover final round) | Sediment (cm of channel deformation) | Density (% cover final round) | Sediment (cm of channel deformation) | Density (% cover final round) |
| | 1.15 | 70% | 1.00 | 70% | 1.00 | 70% | 0.80 | 70% |
| Product A | 0.5611 | 78.116 | 0.7554 | 78.116 | 0.7516 | 78.11 | 0.6931 | 78.116 |
| Product B | 0.3541 | 79.982 | 0.4646 | 79.982 | 0.6154 | 79.982 | 0.6293 | 79.982 |
| Product C | 0.5666 | 92.853 | 0.853 | 92.853 | 0.5930 | 92.853 | 0.59214 | 92.853 |
| Product D | 0.8648 | 71.830 | 0.7565 | 71.830 | 0.8296 | 71.830 | 0.9994* | 71.830 |
| Product E | 0.6784 | 86.574 | 0.7871 | 86.574 | 1.0169* | 86.574 | 1.0642* | 86.574 |
| Product F | 0.7866 | 54.664* | 1.1029* | 54.664* | not tested | not tested | not tested | not tested |
| Product G | 0.9736 | 82.394 | 1.0861* | 82.394 | 1.2780* | 82.394 | 1.32551* | 82.394 |
| Product H | 1.1487 | 56.954* | 1.0671* | 56.954* | 1.0950* | 56.954* | not tested | not tested |
| Product I | 0.4974 | 59.490* | 0.6113 | 59.490* | not tested | not tested | not tested | not tested |

*Unsuccessful performance levels.

Product A: Dense, three-dimensional web of green Polyolefin fibers oriented and mechanically bonded between two nets.

Product B: 100% coconut fiber stitch bonded between a heavy duty UV stabilized bottom net, and a heavy duty UV stabilized middle netting overlaid with a heavy duty UV stabilized top net.

Product C: UV stabilized, three dimensional, multi-layered structure of polyethylene netting.

Product D: Dense web of extra-thick PVC monofilament thermally welded together.

Product E: UV stabilized, three dimensional, polypropylene.

Product F: Machine produced mat of curled wood excelsior with a photo degradable extruded plastic mesh on both sides.

Product G: Three dimensional matrix of heavy nylon monofilaments fused at intersections.

Product H: Biodegradable, Aspen wood fiber with a permanent UV stabilizing netting underlaid with a non-woven textile fabric.

Product I: Woven, undyed jute.

vegetated condition it was 100.49 (2.1 lbs/ft$^2$). When tested in a vegetated condition at TTI, three flexible channel liners protected the channels during test flows in excess of 287 Pa (8 lbs/ft$^2$). The Table 1 presents the levels at which each of the test materials were tested.

## REFERENCES

Chow, Ven Te. 1959. Open-channel Hydraulics. McGraw-Hill Book Company, New York.

Chen, Y.H. and G.K. Cotton. 1986. Design of roadside channels with flexible linings. Hydraulic Engineering Circular No. 15. Federal Highway Administration, FHWA-IP-87-7

Godfrey, S.H., H.C. Landphair and J.A. McFalls. 1993. The performance of flexible erosion control materials. Research Report 1914-1. Texas Transportation Institute, Environmental Management Program.

Godfrey, S.H., H.C. Landphair and J.A. McFalls. 1994. The performance of flexible erosion control materials and hydraulic mulches. Research Report 1914-2. Texas Transportation Institute, Environmental Management Program.

## *BIOGRAPHICAL SKETCH*

***Jett A. McFalls***

*Texas Transportation Institute, Environmental Management Program, Texas A&M University, College Station, TX 77843-3135, USA*

Jett A. McFalls has been with the Texas Transportation Institute's Environmental Management Program since 1990. He has a Bachelor of Landscape Architecture from Texas A&M University. Mr. McFalls is the Principal Investigator of the TxDOT/TTI continuing study of evaluating the performance of flexible channel liners and slope protection and is the manager of the TxDOT/TTI Hydraulics and Erosion Control Field Laboratory. His professional interests are in developing and conducting research related to the issues of hydraulics and erosion control to better understand and manage the complex environmental issues related to natural systems management within the transportation corridor.

# Compost and Wood Chips with Tackifier for Erosion Control

Beverly B. Storey and Jett A. McFalls

Due to legislative mandates, the Texas Department of Transportation (TxDOT) and the Texas Transportation Institute (TTI) Environmental Management Program investigated the use of compost and wood chips with tackifier as erosion control measures. Testing was conducted at the TxDOT/TTI Hydraulics and Erosion Control Laboratory in a simulated highway environment. Three materials were tested with two soil conditions on a 1:3 slope: compost, wood chips with a granular polyacrylamide tackifier, and wood chips with a hydrophilic colloid tackifier. Rain simulations for one-year, two-year, and five-year storm intensities provided data relative to each material's sediment retention performance. Vegetative density coverage data was also collected. Results from preliminary trials suggest that compost and wood chips with tackifier are promising as effective erosion control measures. They outperformed some commercial rolled erosion control materials in vegetation establishment and slope protection at a potentially lower cost.

*Keywords*: Recycling, erosion control, compost, wood mulch, storm water management

## INTRODUCTION

A nationwide expansion of waste reduction mandates, recycling legislation, and environmental campaigns have prompted the Texas Department of Transportation (TxDOT) to modify current right-of-way management activities. One section of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 encourages the environmentally safe use of compost and other products derived from treated municipal sewage sludge by state and local governments along the rights-of-way of federally funded highways. Uses mentioned include highway planting projects, recultivation, and erosion control. The shredding of brush and other green matter for use as mulch and compost is a logical and desirable organic residual management option (Storey, McFalls, and Godfrey 1996).

## COMPOST AND SHREDDED WOOD WITH TACKIFIER STUDY

### Objective

The objective of this research study was to determine the field performance of compost and shredded brush (wood chips) with tackifier as erosion-control materials for use in highway rights-of-way. Test procedures were based upon field performance evaluations conducted in a simulated highway environment.

Test materials for this study were:

- compost consisting of mixed yard debris with biosolids (municipal sewage sludge) processed through a 6.35 mm screen;
- shredded wood (wood chips) processed through a 76 mm screen with a granular polyacrylamide tackifier; and
- shredded wood (wood chips) processed through a 76 mm screen with a hydrophilic colloid tackifier.

The compost and shredded wood materials used for testing were obtained from a municipal composting facility in Bryan, Texas. This facility composts yard wastes and biosolids from a seven county region. The mixture of biosolids, yard waste, and wood chips were thermophylically processed in windrows for 18 to 30 days at 55°C, with agitation every two or three days. The composted material was then left to cure for 30 days. This compost product complies with Environmental Protection Agency (EPA) regulations for unrestricted use of biosolids and Texas Natural Resource Conservation Commission (TNRCC) requirements for use as soil conditioners.

### Methodology

The methods adopted for use in the research study are well developed and have been employed at the TxDOT/TTI Hydraulics and Erosion Control Laboratory (HECL) for five consecutive years. Each test plot is at a scale that adequately represents the highway environment (Godfrey and McFalls 1995).

### Installation — preparation and procedures

The Hydraulics and Erosion Control Laboratory is part of the Texas Transportation Institute's proving grounds in College Station, Texas. The 8.5 hectare facility provides an earthen fill embankment with 70 test plots, two soil conditions, ten at-grade channels, two water reservoirs, pumping stations, rainfall simulators, and various instrumentation. The embankment was built in accordance with the *Texas State Department of Highways and Public Transportation 1982 Standard Specifications for Construction of Highways, Streets and Bridges* (TxDOT 1982). The facility was designed to collect performance data to produce and maintain an approved material list of erosion control products for TxDOT. The outdoor laboratory site has unique physical conditions that provide the most realistic conditions possible for conducting controlled experiments related to the roadside environment (see Fig. 1).

The 1:3 slope test plots used in this study were 6.2 m wide and 21 m down slope. Three of the test plots were sandy loam soils, and three were clay soils. Prior to testing, each of the plots were prepared as follows:

- All sloped test plots were cleared of vegetation and the previous year's soil cap removed.
- Plots were repaired with stockpiled or dug soil and brought back to a uniform, compacted grade.
- The surface was rough graded with a chain link drag.
- Each plot was sterilized with methyl bromide.

The standard seed mixtures were from TxDOT's standard seeding specification published in the *1993 TxDOT Standard Specifications for Construction of Highways, Streets, and Bridges* (TxDOT 1993). Since the laboratory is located in the Bryan District, the rural area species for warm-season perennial vegetation were used. Specific mixtures selected included a mixture for clay or tight soils and a mixture for sand or sandy soils. A slurry of fertilizer and the seed mixture was hydraulically applied, at the recommended rate of 252 kg/ha, with a hydroseeder immediately before material installation.

*Material installations*

A 76 to 101 mm layer of each material was applied to the respective test plots, a material depth consistent


Fig. 1. TxDOT/TTI hydraulics and erosion control field laboratory.

with findings in the literature review (Grille, Canter, and Carsouille 1989; Metro 1994; Virginia Department of Conservation and Recreation 1992; W&H Pacific 1993). The materials were hand-applied using wheelbarrows and rakes. Effort was taken to maintain a consistent 76 to 101 mm layer throughout the test plots. The tackifiers were applied to the shredded wood in a water solution using a hydromulch machine according to manufacturer's instruction. Application rates were 6.75 kg/ha for the granular polyacrylamide and 56 kg/ha for the hydrophilic colloid. The materials, compost and shredded wood with tackifiers, were installed on the clay test plots on 15 May 1995, and on the sand test plots on 26 May 1995.

### Testing procedures and data collection

Test plot data relative to each material's sediment retention performance and vegetative density coverage was collected.

*Rainfall simulation and sediment collection*

The rainfall simulation began on July 19, 1995. Each plot received a series of rainfall simulations: two one-year; two two-year; and two five-year design storms. This allows for increased vegetation establishment prior to the progressively intense rainfall testing. Each simulator unit consists of a series of arms spaced 1.5 m apart, mounted on a steel frame and set approximately 0.60 meters above the ground plane. Rainfall simulations were not done within 24 hours of a natural rainfall or during any natural precipitation or when the wind conditions were prohibitive. Adjacent plots were covered with a plastic film during simulations.

The sediment collection boxes were at the base of the embankment. After each simulated rainfall event, all of the sediment and water were collected, covered, and temporarily stored. The sediment was allowed to settle for at least 24 hours before the top layer of water was vacuumed off and discarded. Soil samples were collected from each bucket and capped, labeled, and stored in the lab office. The remaining soil in the bucket was weighed, recorded, and discarded at this time. Each soil sample was dried to establish the wet/dry ratio for that sample. Finally, the dry sediment weight totals were divided by the number of 10 $m^2$ for each plot to figure total sediment loss.

*Vegetation density data collection*

The vegetative cover was analyzed using the Vegetation Coverage Analysis Program (VeCAP), which calculates the percentage of pixels in a sample image by color. Each plot was subdivided on a graph into a grid of 0.50 $m^2$ sections. A random sampling pattern established with a random numbers table was used to set the sample locations. Thirty (30) samples from the 1:3 slope test plots were recorded with an 8 mm camera positioned perpendicular to the slope surface. The video images were converted to digital images using an image capture board. Each image (sample) was processed with the VeCAP program. The final round of VeCAP was used for determining the percentage of vegetative cover.

### Evaluation criteria

The evaluation criteria was developed through formal, field performance testing at HECL. TxDOT has adopted minimum performance standards for erosion-control blankets, flexible channel lining materials, and hydraulically-applied mulches. In order for a product to be placed on TxDOT's Approved Material List, it must meet the currently adopted performance standards associated with that product. Of the types of materials tested at this facility, the standards for erosion-control blankets were chosen as a basis for evaluation in this study. Although compost and wood chips with tackifier do not have that same physical properties as an erosion control blanket, the performance capabilities of these materials demonstrated in the literature suggested comparable effectiveness (Grille, Canter, and Carsoulle 1989; Metro 1994; Virginia Department of Conservation and Recreation 1992; DeVleeschauwer, Lal, and DeBoodt 1978; Johnson City Trials 1993).

The evaluation criteria used for the compost/shredded wood with tackifier study were:

- In cohesive soils (clay) and a 1:3 or flatter sloped condition, sediment loss should be no greater than 0.34 kg/10 $m^2$. In non-cohesive soils (sandy) and slopes 1:3 or flatter sloped condition, sediment loss should be no greater than 12.21 kg/10 $m^2$.
- In cohesive soils (clay) and 1:3 sloped conditions, vegetation density should reach a minimum coverage of 80% during the testing cycle (growing season-March to November). In non-cohesive soils (sandy) and sloped conditions, vegetation density should reach a minimum coverage of 70% during the testing cycle.

## RESULTS

### Performance analysis

*Compost*

The compost produced 92% vegetation cover on the sand slopes. The vegetative cover on the clay slopes was 99%. A visual survey of the compost plots on sand shows impressive vegetation establishment but, the majority of the vegetation on the sand plot was due to Palmer amaranth (*Amaranthus palmeris*) rather than the seed mix. This is shown in Figs. 2–5, from *The Use of Compost and Shredded Brush on Rights-of-Way for Erosion Control: Final Report* (Storey, McFalls, and Godfrey 1996). The plant height was approximately 2 m. The undesirable seed may possibly have been in the compost itself and germinated upon application to the slope. The clay plot with the same compost, adjacent plots with other erosion control materials, and the

Fig. 2. View of 1:3 clay test plots, 11 weeks post installation. Compost in center of photograph; wood chips with polyacrylamide tackifier to the right of compost plot; wood chips with hydrophilic colloid tackifier, second right of compost plot.

Fig. 4. View of 1:3 sand test plots, nine weeks post installation. Compost, left; wood chips with polyacrylamide tackifier, center; and wood chips with hydrophylic colloid tackifier, right.

Fig. 3. View of 1:3 sand test plots, nine weeks post installation. Control, left; compost, center; and wood chips with polyacrylamide tackifier, right.

Fig. 5. View of 1:3 sand test plots, nine weeks post installation. Compost in center of photograph; wood chips with polyacrylamide tackifier, right of compost; wood chips with hydrophylic colloid, second right of compost.

wood chips with tackifier plots did not show a significant presence of this plant.

The compost on sand plot lost an average of 3.88 kg/10 m$^2$ of sediment during rain simulations. This result exceeds the performance standard for sediment loss for erosion control blankets with the control plot losing 28.576 kg/10 m$^2$. On the clay slope, sediment loss for compost was 0.34 kg/10 m$^2$. This result meets the maximum acceptable sediment loss for 1:3 clay. The control plot for 1:3 clay had a sediment loss rate of 1.3015 kg/10 m$^2$.

The compost maintained its physical properties throughout the test cycle. The material did not significantly shift from its installed position and kept a fairly consistent depth the length of the slope. Contrary to what was anticipated, the compost did not blow to adjacent plots when dry or float when wet. There was minimal damage to the test plots from rill formation.

*Wood chips with granular polyacrylamide tackifier*

The wood chips with a granular polyacrylamide tackifier had vegetative cover results comparable to the compost treatment by producing a 95% vegetative cover on the clay test plot. The sand plot had less satisfactory vegetative cover by producing only 48%. The sediment loss on the sand test plot was 11.27 kg/10 m$^2$, which is 0.93 kg/10 m$^2$ less than the maximum allowable loss. The clay plot lost 0.15 kg/10 m$^2$ of sediment. This is 0.19 kg/10 m$^2$ less than the maximum allowable sediment loss for 1:3 clay treatment.

*Wood chips with the hydrophilic colloid tackifier*

The wood chips with the hydrophilic colloid tackifier produced only a 50% vegetation cover on sand and only 57% cover on clay. Both are below the acceptable minimum. The sand plot lost sediment at a rate of 10.97 kg/10 m$^2$ which is 0.30 kg/10 m$^2$ less than the granular

**Table 1. Performance analysis**

| Product evaluated | Year | Slope | Soil | Maximum allowable sediment loss 0.34 kg/10 m$^2$ | Minimum allowable vegetation density 80% |
|---|---|---|---|---|---|
| Compost | 1995 | 1:3 | Clay | 0.34 kg/10 m$^2$ | 99% |
| Wood chips with polyacrylamide tackifier | 1995 | 1:3 | Clay | 0.15 kg/10 m$^2$ | 95% |
| Wood chips with hydrophylic colloid tackifier | 1995 | 1:3 | Clay | 0.30 kg/10 m$^2$ | 57% |
| Product evaluated | Year | Slope | Soil | Maximum allowable sediment loss 0.34 kg/10 m$^2$ | Minimum allowable vegetation density 70% |
| Compost | 1995 | 1:3 | Sand | 3.88 kg/10 m$^2$ | 92% |
| Wood chips with polyacrylamide tackifier | 1995 | 1:3 | Sand | 11.27 kg/10 m$^2$ | 48% |
| Wood chips with hydrophilic colloid tackifier | 1995 | 1:3 | Sand | 10.97 kg/10 m$^2$ | 50% |

Source: Storey, McFalls, and Godfrey 1996.

polyacrylamide tackifier and 7.09 kg/10 m$^2$ more than the compost on sand plot. The sediment loss for the clay test plot was 0.30 kg/10 m$^2$ which was twice the amount of sediment lost on the granular polyacrylamide plot and slightly less than the compost on clay plot. These results for wood chips with hydrophilic colloid tackifier meet the minimum performance standards for sediment loss, but not for vegetation establishment.

All of the wood chips with tackifier test plots kept a consistent depth of material the length of the slope. The materials did not blow onto adjacent plots and were not transported down slope during rain simulations or natural rainfall events. The test plots did not show any significant damage from rill formation through the test cycle. The shaded areas in Table 1 denote test materials that met or exceeded TxDOT's standards for erosion control blankets.

### Cost comparison of erosion control materials

The cost of the erosion control products currently in the industry varies greatly with product constituents. Using the materials tested at the TxDOT/TTI Hydraulics and Erosion Control Field Laboratory, a comparison of the average material cost of the 5 types of erosion control products are shown in Table 2. These figures are *material cost only* and do not include installation. The material cost of compost is about 20% less than the average organic blanket but approximately three times the cost of the average hydraulically applied mulch application. The wood chips, if taken from right-of-way clearing operations, have a minimal cost. Further research into different application methods (mechanical application rather than hand application), equipment and sources are necessary before feasibility and reasonable cost evaluation can be completed.

**Table 2. Cost comparison of erosion control materials**

| Material | Average cost ($/SM) |
|---|---|
| Synthetic blanket | 3.90 |
| Organic blanket | 1.20 |
| Compost | 0.97 |
| Hydraulically applied mulch | 0.34 |
| Wood chips from ROW clearing operations | minimal |

Source: Storey, McFalls, and Godfrey 1996.

## CONCLUSION AND RECOMMENDATIONS

The results were most encouraging. The compost met the minimum requirements for percentage of vegetative cover and was well within the sediment loss standard on sand and clay required by TxDOT for erosion-control blanket (soil retention blanket). The wood chips (shredded wood) using both tackifiers met the same sediment loss performance criteria used for erosion control materials such as blankets and mulches for sand and clay soils. These results strongly suggest a potential cost savings benefit to transportation agencies. However, further research is needed to verify the results. Further examination of the following issues raised by this project is needed: cost effective application method; type and quality of vegetation; and tackifier types and application rates.

The application of the compost and wood chips for this study was labor intensive (wheelbarrows and rakes). This method would not be cost effective for highway construction or maintenance operations. Alternate application methods, including blowing and/or hydro-seeding equipment, should be examined prior to making any recommendations for field application. Review of potential application methods are under preliminary investigation.

While vegetation coverage using compost was well above the minimum acceptable levels, the characteristics of the vegetation warrant further investigation. The compost material used apparently contained weed seed, Palmer amaranth (*Amaranthus palmeris*), which contributed much of the vegetative cover. For this reason the desired seed mix did not compete well with the undesirable weed seed. Germination of the desired seed mix may also have been retarded by placing the compost and wood chips over the seed using the same installation as many erosion control blankets. In an attempt to ensure the germination of the desired vegetation, application of the seed mixture applied on top of or blended in with the compost needs to be investigated. If a water slurry is used, the seed mixture can be blended and applied by blowing, using the hydro-seeding method to ensure proper seed distribution.

Two different tackifiers were used with the wood chips. The granular polyacrylamide tackifier was applied at a rate of 6.72 kg/ha. The colloidal clay-based tackifier was applied at a rate of 56 kg/ha. The test plots using the granular polyacrylamide tackifier produced almost twice as much vegetation as the colloidal clay-based tackifier. Different tackifiers and their application rates to stabilize different soil types and slopes need to be examined to reinforce the capabilities of using wood chips.

The success of compost and wood chips with tackifier on 1:3 slopes suggests further performance testing on the more demanding 1:2 slopes may be worthwhile. More rigorous tests on the 1:2 slopes will provide a good indication on the limits of each material's effectiveness. The material cost of using compost and wood chips with tackifier is potentially below the average material cost of synthetic and organic blankets. The cost effectiveness of using these materials will be determined by accessibility of materials and more practical application methods. Debris from right-of-way clearing operations may possibly provide a cost effective source for wood chips. Organic waste disposal costs may be dramatically reduced while providing on site erosion control material. Compost sources are located throughout the State of Texas with new composting facilities emerging. With the testing done thus far, compost and wood chips with tackifier have demonstrated remarkable results. Further investigation to replicate results, confirm conclusions, and modify the application methods needs to be conducted before being recommended for use by transportation agencies as an erosion control material.

## REFERENCES


DeVleeschauwer, D., R. Lal, and M. DeBoodt. 1978. The comparative effects of surface applications of organic mulch versus chemical soil conditioners on physical and chemical properties of the soil and on plant growth. Cantena, 5: 337–349.

Godfrey, S.H., and J.A. McFalls. 1995. The 1994 performance results for erosion-control blankets, mulches, and channel liners. Research Report 1914-4. Texas Department of Transportation, Division of Maintenance and Operations.

Grill, J.J., J.P. Canter, and J. Carsoulle. 1989. The benefits of permanent grass and mulching for limiting runoff and erosion in vineyard: Experiments using rainfall-simulation in the Beaujoulais. Soil Technology Series, I: 157–166.

Metro. 1994. Summary of projects using yard debris compost for erosion prevention and control. Final report.

Storey, B.B., J.A. McFalls, and S.H. Godfrey. 1996. The use of compost and shredded brush on rights-of-way for erosion control: final report. Research Report 1352-2F. Texas Department of Transportation.

Texas State Department of Highways and Public Transportation. 1982. Standard specifications for construction of highways, streets and bridges. Washington, D.C.

Texas Department of Transportation. 1993. Standard specifications for construction of highways, streets, and bridges. Washington, D.C.

Utilization of municipal solid waste compost: research trials at the Johnson City, Tennessee Facility. 1993. Compost Science & Utilization, Spring: 42–48.

Virginia Department of Conservation and Recreation. 1992. Virginia Erosion and Sediment Control Handbook. Division of Soil and Water Conservation.

W&H Pacific. 1993. Demonstration project using yard debris compost for erosion control. Final report.


## *BIOGRAPHICAL SKETCHES*


***Beverly B. Storey***

*Texas Transportation Institute*
*Environmental Management Program*
*Texas A&M University System*
*College Station, TX 77843-3135, USA*


Beverly Storey has been with the Texas Transportation Institute's Environmental Management Program since 1993. She has a Bachelor of Science degree in Forestry and Master of Landscape Architecture degree from Texas A&M University. Her research focus has involved highway noise abatement technologies, visual quality related to the highway environment, and the use of recycled materials in highway design. Ms. Storey is also working with roadside design and development plans for safety, maintenance and aesthetics for the Texas Department of Transportation's Construction Landscape Program.

***Jett A. McFalls***
*Texas Transportation Institute*
*Environmental Management Program*
*Texas A&M University System*
*College Station, TX 77843-3135, USA*

Jett A. McFalls has been with the Texas Transportation Institute's Environmental Management Program since 1990. He has a Bachelor of Landscape Architecture degree from Texas A&M University. Mr. McFalls is the Principal Investigator of the TxDOT/TTI continuing study of evaluating the performance of flexible channel liners and slope protection and is manager of the TTI Hydraulics and Erosion Control Field Laboratory. His professional interests lie in developing and conducting research related to the issues of hydraulics and erosion control to better understand and manage the complex environmental issues related to natural systems management within a transportation corridor.

# Part XI
# Pesticides

# Vegetational Succession Following a Broadcast Treatment of Glyphosate to a Wild Reed Stand in a Utility Right-of-Way

**Michael R. Haggie, Richard A. Johnstone, Roland J. Limpert, and Hubert A. Allen**

Tree, shrub, and herbaceous vegetation succession is documented following an aerial broadcast application of glyphosate, and subsequent selective applications, to a non-tidal wetland on a Delmarva Power right-of-way (ROW) in central Delaware. Herbaceous vegetation was initially dominated by the ecologically invasive, non-native, wild reed (*Phragmites australis*), while woody vegetation was dominated by undesirable red maple (*Acer rubrum*) and black willow (*Salix nigra*). The herbicide treatment resulted in the elimination of almost all vegetation in the initial year post-treatment. However, 65 ecologically desirable herbaceous and only one undesirable species were present within two years post-treatment. Species compositional changes over the five year study period are discussed, with emphasis on compatibility with the operation and maintenance of a ROW, and the effect on biodiversity and wildlife habitat potential. The relative dominance of desirable and undesirable herbaceous and woody vegetation is documented.

*Keywords*: Right-of-way (ROW), succession, herbicide, *Phragmites*, Delaware, relative dominance, frequency, herbaceous, shrub

## INTRODUCTION

Up until the mid 1950s, electric utility rights-of-way (ROW) were largely mechanically mown to remove interfering tall trees to aid ease of access for maintenance and distribution of energy (Nowak et al. 1993). This method required use of heavy machinery and manpower in an inherently arduous work environment (Hallmark 1996) involving repeat treatments every two to four years. The time interval depended upon the types of vegetation encountered.

The 1960s heralded an era of broadcast herbicide control of undesirable plant species which was followed by nearly two decades of selective control, lasting until the 1980s. With public opinion being at odds over the use of herbicides during the 1990s, an Integrated Vegetation Management (IVM) system has evolved which employs a combination of control methods. IVM incorporates handcutting, mechanical control, chemical techniques, cultural methods, and biological control (Hallmark 1996). (Note: for this study undesirable species include those that will grow to a sufficient height so as to interfere with overhead wires.)

Since 1986, Delmarva Power (DP) has gradually implemented some IVM methods in ROW management, particularly the selective use of herbicides along with a high degree of field crew education concerning the identification of desirable and undesirable shrub and tree species. These methods have not only produced a significant cost savings to the company of $3 million (Johnstone 1997, personal communication), but have also created over 3,642 ha (9,000 acres) of potential wildlife habitat along 9,171 km (5,700 miles) of ROW in Maryland, Delaware, and Virginia (Wildlife Habitat Enhancement Council 1992). Much of this is ecologically termed "old-field" type, which can have considerable value for certain wildlife species (Chasko and Gates 1982, Delorey 1992, Bramble et al. 1987, Smith 1966).

The initial investment into an IVM program in terms of labor, machinery and herbicide costs are relatively intense. However, these inputs peak in the first two years of the program's implementation (Johnstone 1993), ultimately creating a system of reduced annual costs versus regular mowing. From a frequency and timing point of view, mowing can be very damaging to ground nesting wildlife (Rosene 1969). The habitat produced through IVM is often of higher quality because of greater plant diversity for species needing blocks of undisturbed shrub habitat with little or no human disturbance.

The ultimate objective of this type of management is to create relatively stable and desirable shrub/herbaceous communities that evolve to outcompete undesirable tall growing trees. This situation can be achieved with a gradual reduction of herbicide use, ending with only periodic spot treatment (Bramble et al. 1991).

Delmarva Power (DP) has contracted with Chesapeake Wildlife Heritage (CWH) to evaluate the effects of several herbicide and mechanical treatments of sections of ROW in Maryland and Delaware. This paper describes plant species succession following an aerial broadcast treatment and subsequent spot treatments with glyphosate of a mixed deciduous shrub swamp dominated by a monospecific herbaceous stand of *Phragmites australis* (Gav.) Trin.

## STUDY AREA AND SITE HISTORY

Located at the Abbott's Mill Nature Center near Milford, Sussex County, Delaware, the study area lies at coordinates 38°53'N and 75°30'W. The overlying soils are hydric. The immediately adjacent non-hydric upland and underlying soil type is Johnston silt loam, in the Evesboro-Rumford Association (Ireland and Matthews 1974).

The area encompasses a 50 m wide section of DP electric transmission line right-of-way that passes through secondary regrowth mixed forest and shrub wetland (Tiner 1988) for 150 m.

The utility power line was originally constructed in 1968, and up until 1983 had been mown every three years by the utility company contractor. Wishing to eliminate the use of mowers in the wetland area, the owners (Delaware Nature Society) offered to hand clear the wetland area themselves of undesirable tree species using volunteers.

By 1990, the hand clearing had not adequately been performed, resulting in three species (taxa), two undesirable and one desirable (see Fig. 2), attaining tree dimensions (≥ 5 cm) and threatening the reliability of the electric conductors. The wetland herbaceous community had also become dominated by an almost monospecific stand of *Phragmites australis* (see Fig. 1). In October 1990, in a cooperative program of *Phragmites* control with Delaware Fish and Wildlife Service, DP had an aerial treatment of glyphosate herbicide applied at a rate of 10.44 l/ha (4 qts/acre) of glyphosate, 53.8% active ingredient (a.i.).

This study follows the tree, shrub, and herbaceous plant succession that colonized this site over the ensuing five years.

## METHODS AND MATERIALS

Baseline data of tree, shrub and herbaceous species were taken prior to broadcast aerial application of herbicide in

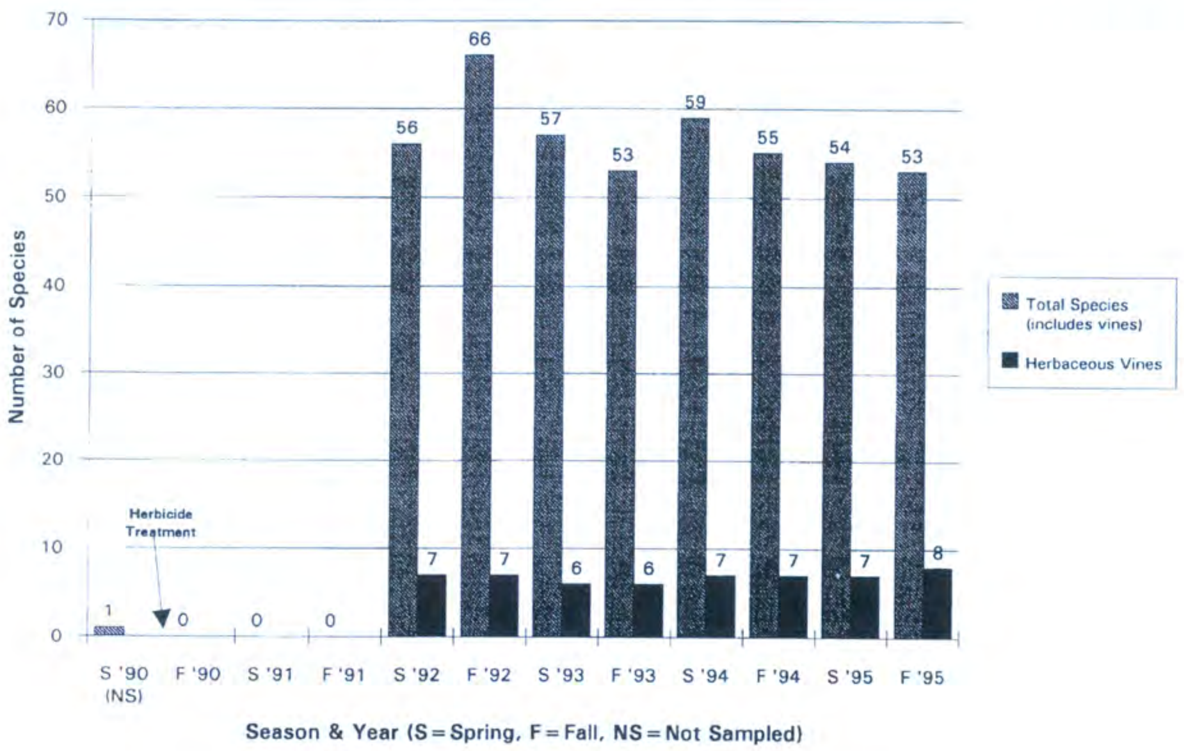



Fig. 1. Abbott's Mill herbaceous six year progression.

the fall of 1990. The herbicide used was Rodeo, which is an isopropylamine salt of N-(phosphono methyl) glycine (common name: glyphosate isopropyl/ammonium) (Meister and Sine 1996).

A linear transect survey method was used because of this method's suitability to follow long term vegetation succession (Smith 1966). A 50 m wide by 70 m long centrally located section of ROW was selected as a site that was representative of the wetland (hydric) vegetation to be surveyed. Ten 2×20 m shrub plots, 10 m apart were established, five on either side of the 10 m wide central maintenance track, which was not surveyed. Shrub survey lines were commenced 10 m from one end of the survey block. Two tree plots, 20×50 m, were established, one on either side of the maintenance track. The end points of each transect line were marked with stakes which allowed the same transect to be resurveyed in subsequent years.

Herbaceous plots 1 $m^2$ were laid out along the central line of the shrub plots every 5 m. The 5 m points were permanently marked with wire flags. At either end of the transect, 5 m was left to reduce the effects of (1) edge shading from the adjacent woodland and (2) upland plant species competition from the central maintenance track (see Fig. 5).

In the tree plots, individuals were identified to species where possible, counted and measured at diameter at breast height (DBH). Woody specimens ≥5 cm were considered trees. In the shrub plots, specimens were identified to species, and stem count taken. Woody specimens ≤5 cm were considered shrubs, based on size, morphology, and management practices. Undesirable woody species are problematic to the management of the ROW if they succeed in dominating and outcompeting other species. Only when they reach a stage ≥5 cm are they controlled by the utility company. Natural competition from seedling to 5 cm eliminates many individuals (Odum 1971).

Herbaceous vegetation was stem counted and percent cover taken following species identification. All specimens were identified to genus, and to species, where practicable. A prefabricated 12.5 mm (half-inch) PVC meter square was used along the survey line, within which the data were taken.

Tree, shrub and herb data were collected in the fall from 1990 through 1995. Herbaceous data were collected in the fall from 1990 through 1995 and in the spring from 1991 through 1995.

A relative dominance index (RDI) was developed for this study to compare the various species groups to each other and between seasons and years. The RDI was calculated by the equation:

$$\text{RDI of species A} = \frac{\text{Dominance of species A in season X}}{\text{Frequency of species A in seasonX}}$$

Dominance was defined as the total number of individuals divided by number of plots in the survey for shrubs and trees, and average percent area coverage divided by the number of plots in the survey for herbaceous species.

$$\text{Frequency of species A} = \frac{\text{Number of plots species A found}}{\text{Total number of plots}}$$

Frequency was defined as the number of plots on which a species is found divided by the total number of plots in the survey. The RDI scores for each species can be combined to provide scores for desirable, undesirable and woody vine species groups for each season and year of the study. A high RDI 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 RDI value.

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

## RESULTS AND DISCUSSION

In September of 1990 the entire wetland section of the utility ROW was aerially treated with a broadcast application of glyphosate, including the survey area. The shrub swamp was dominated by desirable and undesirable woody species (see Fig. 2), including three tree species. The herbaceous vegetation was almost entirely composed of *Phragmites australis*.

One month later all woody vegetation was superficially dead in the survey area. A few scattered living specimens of *Phragmites australis* were noted outside the shrub transects. The herbaceous plots consisted entirely of dead vegetation, mainly *Phragmites*.

In the spring and fall of 1991 again all herbaceous plots comprised of dead vegetation. In the fall of 1991 a few scattered specimens of *Phytolacca americana* L., *Polygonum* sp., *Mikania scandens* (L.) Wild., *Aster* sp. and *Panicum* sp. were found outside the herbaceous plots. The shrub plots comprised of a few specimens of resprouted *Acer rubrum* and *Rhus glabra* and a group of *Amelanchier* on transect 8.

The spring of 1992 shows a dramatic increase in the numbers of herbaceous species (56), with a five year peak of 66 species in the fall. Thereafter from the spring of 1993 to the fall of 1995 the number drops slightly and oscillates between 53 and 59 species (see Fig. 1). This may suggest a long term settled equilibrium. There was no correlation to the amount of rainfall. The herbaceous RDI increases rapidly to 79.3 in the first two years post-treatment and then plateaux at around 78 in years three to five (see Fig. 4). The number of herbaceous vine species holds very constant through the post-treatment survey. The high number of herbaceous species in the fall of 1992 may be attributed to initial lack of competition from woody/shrub vegetation. As the RDI of

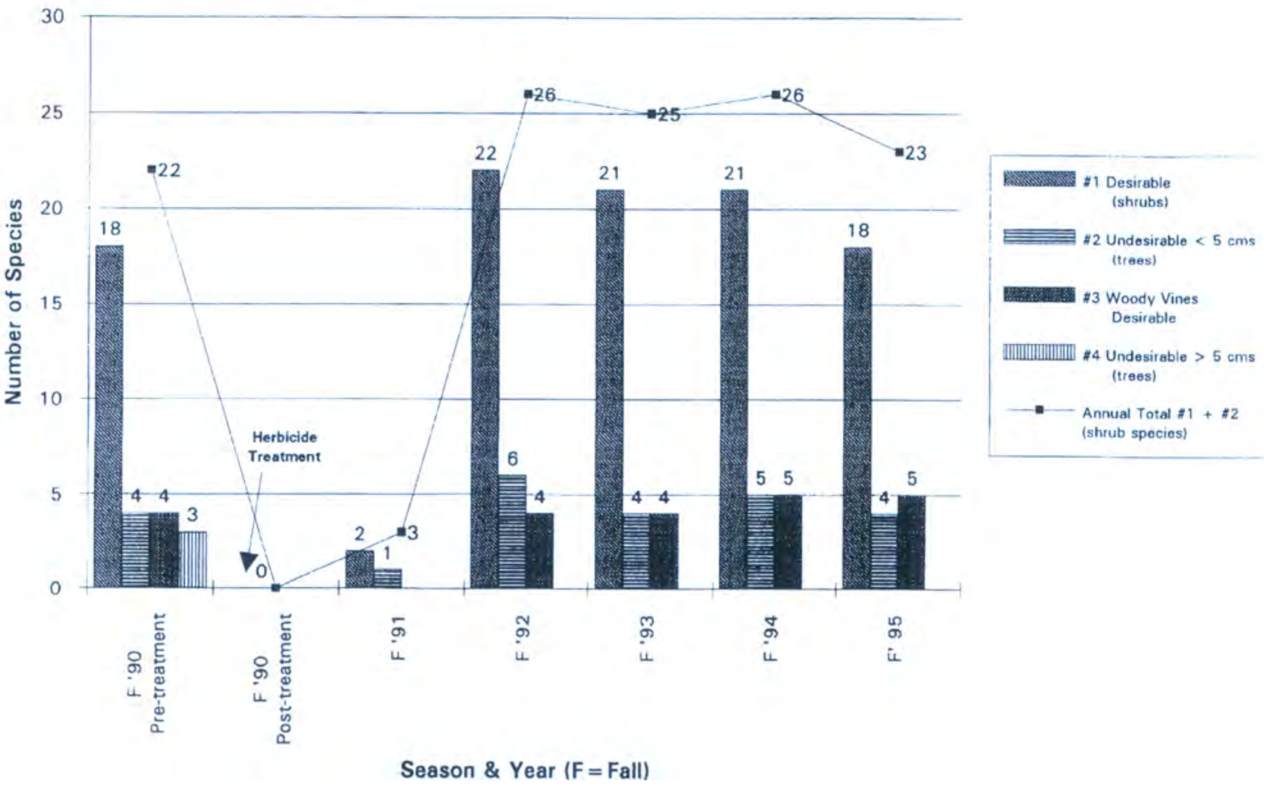
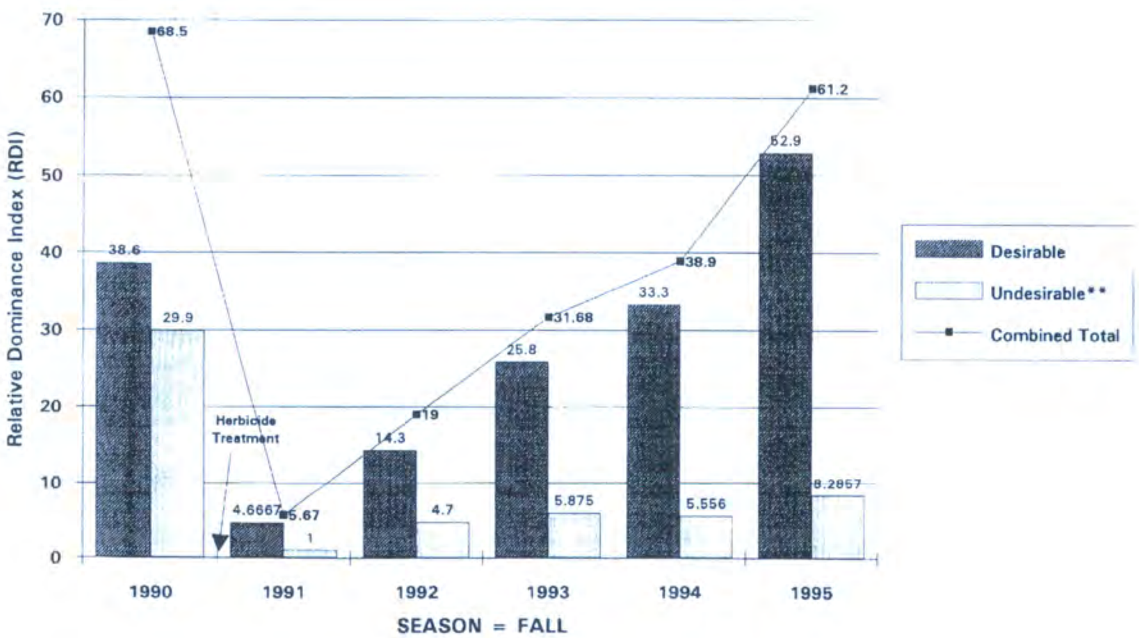



Fig. 2. Abbott's Mill woody/shrub six year progression.




* (≤ 5 cms) DBH shrubs and trees

** Undesirable species include those species that will grow to a sufficient height so as to interfere with overhead utility wires

Fig. 3. Abbott's Mill woody/shrub species relative dominance six year progression.

woody species increases, the number of herbaceous species settles back to oscillate between 53 and 59 in the years 1993–1995 (see Fig. 3).

Baseline shrub data was taken in the fall of 1990 just prior to herbicide treatment. No live specimens were counted one month post-herbicide application; all specimens at that date were ostensively considered dead. A few resprouted *Acer* and *Rhus* specimens were counted in the fall of 1991 (RDI 4.67, see Fig. 3.). As with the herbaceous species, 1992 shows a dramatic increase in woody/shrub, both desirable and undesirable, and woody vine species with a peak over the survey period of 26 species in the second year post-treatment. This level is held fairly constant through 1994, when in 1995 a slight decline in desirable species is noted. Again this may be due to interspecific competition as the RDI increases to 52.9 in 1995. Undesirable and woody vine species hold fairly constant through the post-treatment years.

In summary, a monospecific stand of non-native wild reed was virtually extirpated and replaced with a stable community of 53 native herbaceous species with an RDI of 78 within five years following a broadcast application of glyphosate herbicide. In contrast numerical diversity in the shrub community is restored in five years post-treatment, with a numerical increase in three of the four intervening years. Compositionally the woody/shrub community loses five species following herbicide treatment, but gains 12 new species after five years. The number of undesirable woody species holds fairly constant in the year pretreatment and in years 2–5 post-treatment.

Despite adverse public reaction to the use of pesticides in recent years, this study shows that herbicide use, reduced over time to spot treatments, can create diverse managed plant communities that benefit both energy distribution and wildlife. A diversity of undisturbed flora will lead to a diversity of vertebrates and invertebrates. Thus judicious herbicide use has a valid place in modifying disrupted vegetational areas to bring about a system that is more representative of a natural community as well as serving human social needs in an already perturbed environment.

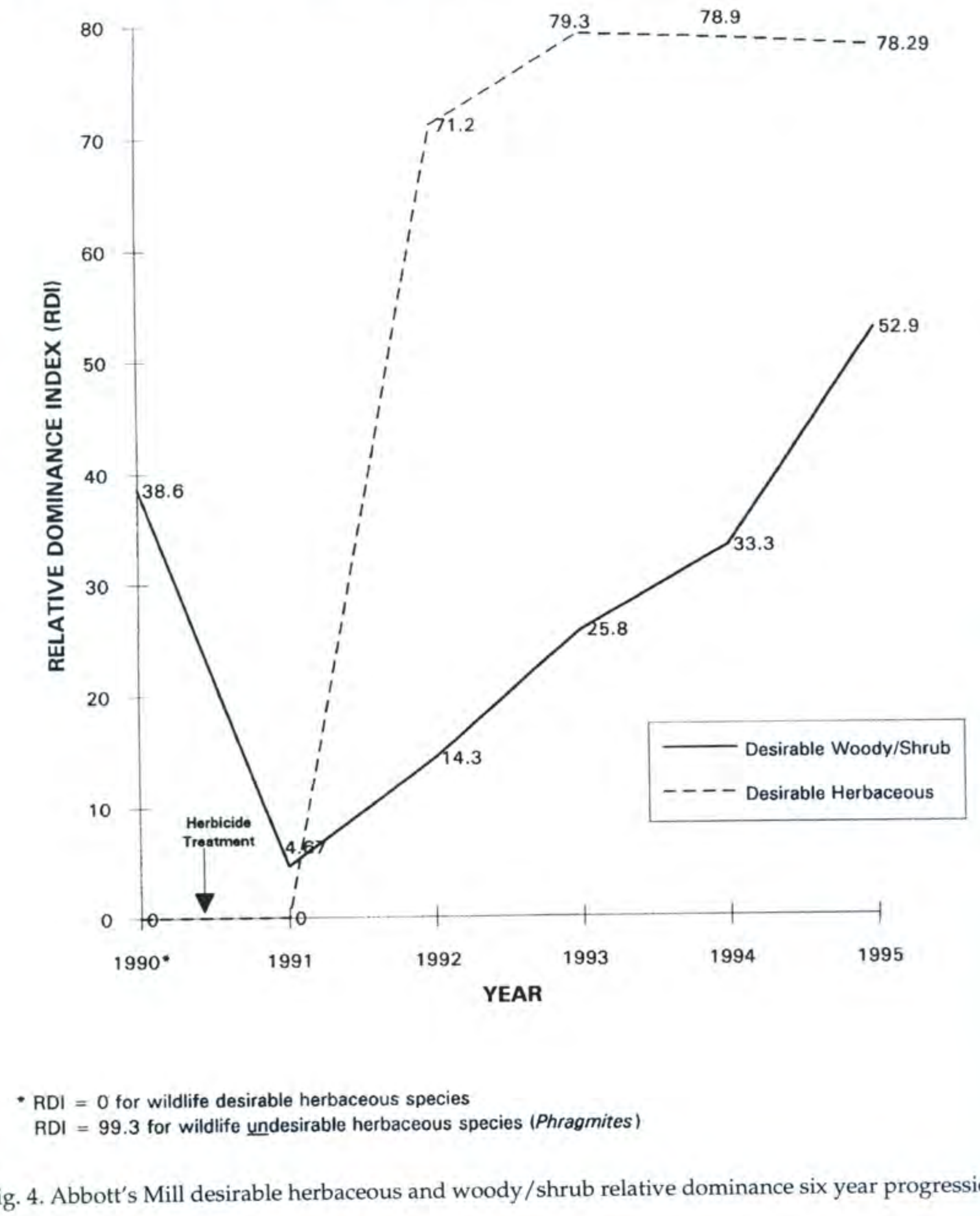



Fig. 4. Abbott's Mill desirable herbaceous and woody/shrub relative dominance six year progression.

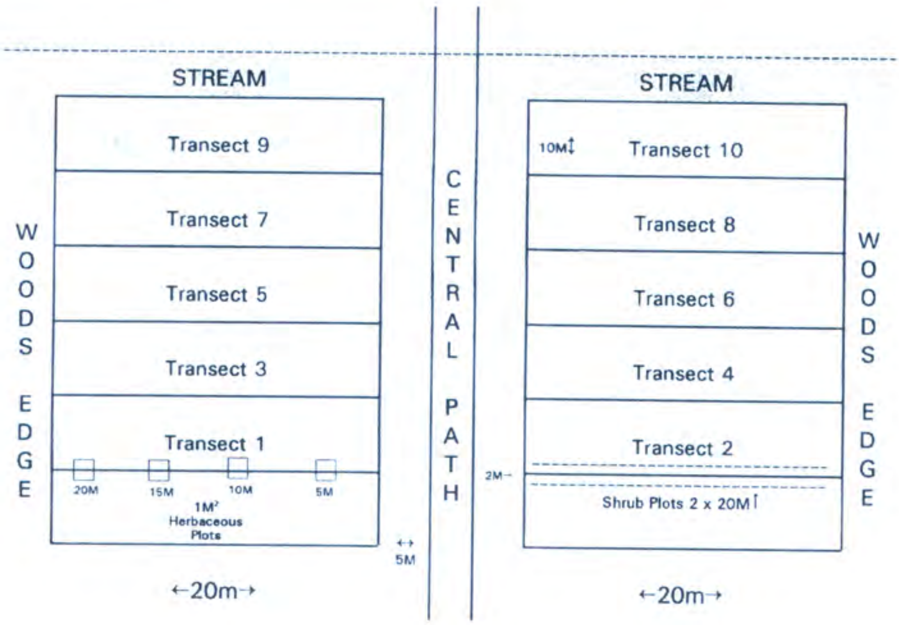



Fig. 5. Survey design and layout, Abbott's Mill, Houston, Delaware.


## ACKNOWLEDGEMENTS

Bob Molzhan, Environmental Affairs, Delmarva Power & Light, for initial funding of the research project; Victor Williamson, Forestry Representative, Delmarva Power & Light, for collaboration in ROW management; Deborah Collison, Chesapeake Wildlife Heritage, for data entry/analysis and graphics presentation; Dave Williams, Anne Arundel Community College, for botanical identification; Dana Limpert, Henry Clifford, and George Clifford for their field assistance; and Delaware Nature Society for giving us their permission to use the study site.


## REFERENCES


Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1987. Development of plant cover diversity on an electric transmission right-of-way. In: Proceedings of the Fourth Symposium on Environmental Concerns in Rights-of-Way Management. 25–28 October.

Bramble, W.C., W.R. Byrnes, R.J. Hutnik, and S.A. Liscinsky. 1991. Prediction of cover type on rights-of-way after maintenance treatments. Journal of Arboriculture, 17(2): 38–43.

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

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

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.

Delorey, A. 1992. The power line right-of-way: An unexpected place to find many nesting birds. Birding, 24(6): 365–367.

Hallmark, S. 1996. IVM: A competitive tool in electric perspectives. May–June, pp. 16–28.

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. 1993. Vegetation management with environmental stewardship. Paper presented at the Fifth International Symposium on Environmental Concerns in Rights-of-Way Management. Montreal, Quebec, 19–22 September.

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

Meister, R.T., and C. Sine, eds. 1996. Farm Chemicals Handbook. Meister Publishing Company, Willoughby, Ohio, p. C196.

Nowak, C.A., L.P. Abrahamson, D.J. Raynal. 1993. Powerline corridor vegetation management trends in New York State: Has a post-herbicide era begun? Journal of Arboriculture, 19(1): 20–25.

Odum, E.P. 1971. Fundamentals of Ecology. W.B. Saunders Co., Philadelphia, Pennsylvania, 574 pp.

Rosene, W. 1969. The Bobwhite Quail, Its Life and Management. Rutgers University Press, New Brunswick, New Jersey, 418 pp.

Shuttleworth, F.S. and H.S. Zim. 1967. Mushrooms and Other Non-flowering Plants. Western Publishing Company, Inc., Racine, Wisconsin, 160 pp.

Smith, R.L. 1966. Ecology and Field Biology. Harper & Row, New York, New York, 686 pp..

Tiner, R.W., Jr. 1988. Field guide to non-tidal wetland identification. Maryland Department of Natural Resources, Annapolis, Maryland and U.S. Fish and Wildlife Service, Newton Corner, Massachusetts. Cooperative publication. 283 pp. and plates.

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

## BIOGRAPHICAL SKETCHES

*Michael R. Haggie*

*Chesapeake Wildlife Heritage, P.O. Box 1745, Easton, MD 21601, USA*

Michael R. Haggie is a Wildlife Ecologist with Chesapeake Wildlife Heritage in Easton Maryland. His work focuses on wildlife ecology of utility rights-of-way and sustainable farming systems. He received a B.Sc. in Agronomy from Cornell University.

*Richard A. Johnstone*

*Delmarva Power & Light Company, P.O. Box 1739, Salisbury, MD 21802, USA*

Richard A. Johnstone is Supervisor of Forestry for Delmarva Power & Light Company in Salisbury, Maryland. He serves on Edison Electric Institute's Vegetation Management Task Force and is the Vice-president of the Utility Arborist Association. He received a B.S. degree in Forest Resources Management from West Virginia University.

*Roland J. Limpert*

*Power Plant & Environmental Review Department, Maryland Department of Natural Resources, Tawes State Office Building, #B3, Annapolis, MD 21401, USA*

Dr. Roland J. Limpert is an Environmental Specialist with the Maryland Department of Natural Resources in Annapolis, Maryland. Currently he is involved in research projects on Tundra Swans and Canada Geese. He holds a doctorate in ecology from Johns Hopkins University.

*Hubert A. Allen*

*Hubert Allen & Associates, La Mirage Apt 2126, 10700 Academy Road, NE, Albuquerque, NM 87111, USA*

Hubert Allen, President of Hubert Allen & Associates, has a Master's of Science Degree in Biostatistics from Johns Hopkins University and operates a consulting firm specializing in "Statistics/Computing/Information Systems in Health and Environment".

# Pentachlorophenol in Soil Adjacent to Utility Poles in New York State

Edward F. Neuhauser, Ishwar P. Murarka, Scott Shupe, and Martha Mayer

In cooperation with the Electric Power Research Institute, Niagara Mohawk Power Corporation completed detailed soil sampling and analyses to determine distributions of chlorophenols in the vicinity of in-service utility poles in New York State and biodegradation rates. Samples were aligned along cardinal compass directions and collected from four depths at 7.6, 20.3, 45.7 and 76.2 cm (3, 8, 18, and 30 in) from poles. Sample depths varied with pole length. The species of wood and pole age showed little effect on distribution of chlorophenols in soil. The release of leached pentachlorophenol (PCP) was shown to be limited to short distances from the poles, 7.6 cm (3 in) mainly. The majority of maximum PCP concentrations in soil were less than 100 mg/kg and occurred in surface and shallow samples. Secondary tetrachlorophenols and trichlorophenols, which occur in PCP treatment solutions, showed distributions in soil similar to PCP. Soil pH for samples from the Adirondack region was relatively lower than for samples from other regions. The frequency of high PCP concentrations was greater for the Adirondack area samples than for samples from the other state areas. The average half-life of PCP in New York soil during laboratory studies was less than three years. The results of the sampling and laboratory testing demonstrate that site-specific factors influence the behavior of PCP in the vicinity of in-service poles.

*Keywords*: Soil, biodegradation, New York State, chlorophenols, tetrachlorophenols, trichlorophenols, pentachlorophenol, preserved wood pole

## INTRODUCTION

Wood transmission and distribution system poles used by utility companies are commonly preserved with pentachlorophenol (PCP). In the United States, approximately 3% of an estimated 60 million poles are replaced annually. The United States Environmental Protection Agency (EPA) has regulated PCP and associated chlorophenols: 2,4,5-trichlorophenol and 2,4,6-trichlorophenol, under the toxicity characteristic (TC) rule since 1990 (Federal Register 1990). Safe drinking water standards established in 1991 set the maximum contaminant level (MCL) for PCP at 0.001 milligram per liter (mg/l). The EPA is expected to modify the TC limit for PCP eventually because drinking water MCLs are a basis used for establishing TC limits.

The distribution of PCP in soil adjacent to utility poles was investigated by the Electric Power Research Institute (EPRI) across the United States (EPRI 1995a), including an expanded sampling scope in New York state. These studies involved sampling and analysis of soil in the vicinity of utility poles, and biodegradation and attenuation studies of PCP in soil samples from near the poles. Methods and findings for the New York pole study involving 31 poles (30 distribution, one transmission) are published in a March 1995 report (EPRI 1995b). The field and analytical methods were the same as those used for EPRI's national study. Niagara Mohawk Power Corporation (NMPC), New York State Electric and Gas Corporation (NYSEG), Rochester Gas and Electric Corporation (RG&E), and the Empire State Electric Energy Research Company (ESEERCO) co-sponsored the New York pole study.

None of the New York sample sites was located in the Adirondack Park area (Fig. 1). Therefore, NMPC undertook a supplemental study of 12 poles (10 distribution, two transmission) to evaluate distribution of PCP in soils typical of those found in the Adirondack Park.


Fig. 1. Locations of sampled New York State utility poles.

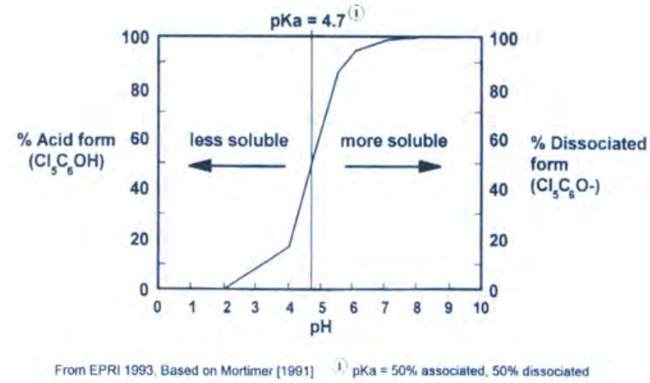



Fig. 2. Speciation of PCP as a function of pH.

The objectives of both the EPRI and NMPC studies were as follows:

1. to determine the distribution of chlorophenols in soil collected adjacent to in-service utility poles;
2. to estimate attenuation coefficients for PCP in soil; and
3. to estimate the rate of PCP biodegradation in soils.

This paper conveys the observations and findings for the New York pole studies in reference to the distribution of chlorophenols in in-service utility poles and in soil adjacent to utility poles, and the results of biodegradation tests. The retention levels of preservative in individual poles at treatment were not known. The concentrations of PCP in representative wood core samples were measured during the studies.

## BACKGROUND

### Soil types

Sampling locations for the original study were governed by the geographic location for service areas of participating utilities. Four general soil groups were predesignated for investigation during the second study, in the Adirondack region. These included wetlands soil, sand, cobbly soil, and till or lacustrine deposits, in an attempt to group soil samples for which the behavior of PCP leachate was expected to be similar. Most data from the original study can be grouped with the four soil categories of the supplemental study, based on observations in boring logs and results of grain-size analysis. Soil conditions at 12 poles from the original study were not consistent with placement within any of these categories due to the predominance of silt and clay at those locations. For purposes of this paper, the findings are grouped by study (i.e., original or supplemental).

### Solubility of PCP

PCP is an acidic phenol with ring chlorines that resist displacement (EPRI 1993). It dissolves in most organic solvents in percentage amounts but, in water solubility is pH dependent and is in tens of parts per million range. At pH 4.7, the $pK_a$, one-half of the PCP is present in the non-polar phenolic acid form and one half in the ionized, phenate form (Fig. 2).

The effect of pH on the form of PCP influences the behavior of PCP in soil and groundwater through solubility and sorption phenomena. The primary role of pH in adsorption of PCP has been proven experimentally (Christodoulatos et al. 1994). Relatively higher levels of ionized PCP go into solution as pH increases above 4.7. For pH < 7, as pH decreases, the quantity of the non-polar form increases, increasing sorption of PCP to soil particles. The non-polar form retains its hydrophobic nature, which produces an affinity for organic material (O'Brien and Gere 1992). As the level of organic substance in the soil increases, the level of PCP sorption will increase. Because a dynamic balance occurs between ionized and non-polar forms of PCP, the solubility of PCP for a given quantity entering the environment is variable, depending on pH and organic content of the soil.

In natural water systems that tend to be more basic than acid, PCP is present chiefly in the dissociated form and is more readily mobile due to reduced adsorption (Lafrance, Marineau, Perreault and Villeneuve 1994). Conditions of acidic surface and groundwater would tend to produce less mobility, resulting in higher detectable concentrations in sediment or soil.

Solvents used with PCP treatments can influence the mobility of PCP (Christodoulatos et al. 1994). Use of solvents that promote wood swelling will facilitate sorption of PCP on cell walls, resulting in reduced release of PCP over time. However, free-phase solvents in the environment increase the mobility of PCP because the PCP will tend to remain dissolved rather than become fixed to soil particles. The solvent typically used with PCP for wood pole treatments is diesel petroleum.

## METHODS

### Sampling

For both studies, a sampling grid was created to establish sample locations. Four hole locations were aligned on each of four spokes radiating from the pole along the four cardinal directions (true north, east, etc.), using a compass set to the local declination. The holes on each spoke were located at a distance of 7.6, 20.3, 45.7 and 76.2 cm (3, 8, 18, and 30 in) from the pole. A ring sampling design resulted. For transmission poles with heights exceeding 18.3 m (60 ft), samples were added to each spoke at a distance of 121.9 cm (48 in) from the pole. Background soil samples were collected at locations approximately 3 m (10 ft) upgradient of the pole to investigate the characteristics of native soil at areas not influenced directly by PCP leachate from the poles. Supplementally treated poles were avoided during both studies.

Samples were obtained from four depths within each hole: top or surface, shallow, mid-depth, and deep. The poles investigated in New York ranged in length from 10.7 to 27.4 m (35 to 90 ft); burial depth of the poles varied with length. Subsurface-soil samples were positioned in reference to the butt end of the poles, with the deep samples located 0.6 m (2 ft) deeper than the pole burial depth or at a maximum of 3.6 m (12 ft). Sloping or uneven topography dictated the use of a point on the pole, called a datum point, from which to standardize the depth to each sample at a pole. Mechanics of sampling, sample handling and field decontamination have been described previously (EPRI 1995b).

### Analyses

Based on findings during the national EPRI pole study, each sample from the 7.6 and 20.3-cm (3- and 8-in) rings was analyzed separately to focus on the area of highest concentrations of PCP in soil near poles. Samples from the four depths in the 45.7-, 76.2-, and 121.9 cm (18-, 30-, and 48-in) rings were composited by hole. A known volume of soil from each sample for a given hole was placed in a decontaminated stainless-steel bowl covered with aluminum foil between samples. The soil was homogenized once soil was collected from all four soil intervals and a composite sample was retrieved.

Biodegradation (mineralization) and attenuation testing was conducted on composited samples from the background location using EPA protocols, 40 CFR 796.3400 and 40 CFR 796.2750, respectively. The work was undertaken at the Utah State University Water Research Laboratory for both the EPRI and NMPC studies.

Five physical/chemical parameters were measured in samples from the 20.3-cm (8-in) ring and the background location at each pole: pH, total organic carbon (TOC), cation exchange capacity (CEC), grain size, and percent moisture.

Samples of pole wood were collected from representative distribution poles during each study. A sample of the outer 5.1 cm (2 in) of the pole wood was collected with a 0.5-cm (0.2-in) diameter wood borer, 0.3 m (1 ft) above ground surface, aligned with the north spoke. The wood sample was analyzed for chlorophenol content.

A microscale solvent extraction (MSE) method, a modification of EPA Method 8040 developed by EPRI, with quantitations based on flame ionization and electron capture detection, was used for analysis of PCP and associated chlorophenols for soil and wood samples.

Standards for identification and quantitation used with MSE include the following constituents:

2,4-dichlorophenol
2,3,5-trichlorophenol
2,4,5-trichlorophenol
2,4,6-trichlorophenol
2,3,4-trichlorophenol
2,3,6-trichlorophenol
2,3,5,6-tetrachlorophenol
2,3,4,6-tetrachlorophenol
pentachlorophenol

## RESULTS AND DISCUSSION

### Pole characteristics

The predominant category of wood represented by the sampled poles was Southern pine (Fig. 3), a general category comprised of six species. Western red cedar and Douglas fir were also represented. The ages of sampled poles ranged from 6 to 26 years (Fig. 4). Poles investigated during the original study were generally younger than the poles investigated during the supplemental study. While the age of the pole does not correspond necessarily to the years in service, the difference in distribution of pole age between the two studies is large enough to allow the conclusion that poles from the supplemental study tend to represent longer periods of leaching than do poles from the original study.

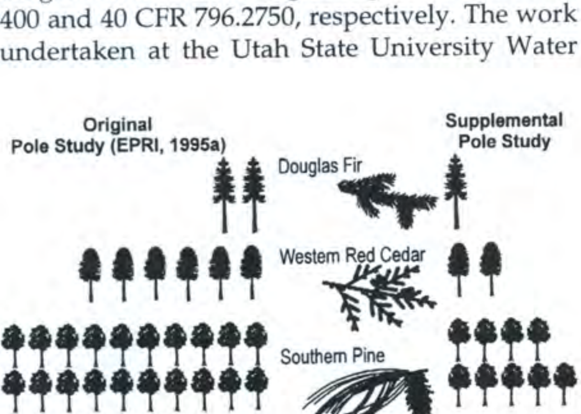



Fig. 3. Distribution of wood pole species.

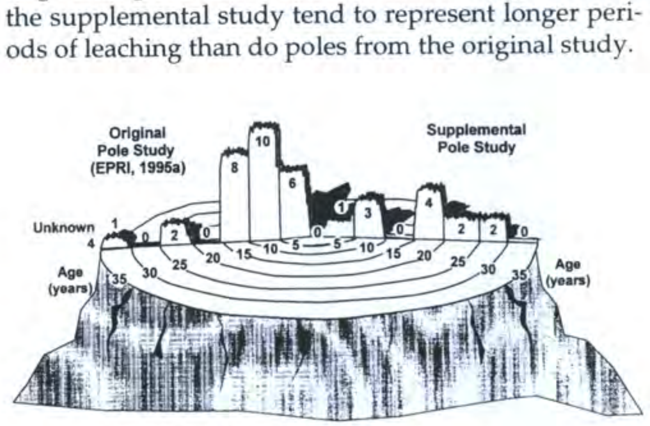



Fig. 4. Distribution of wood pole ages.

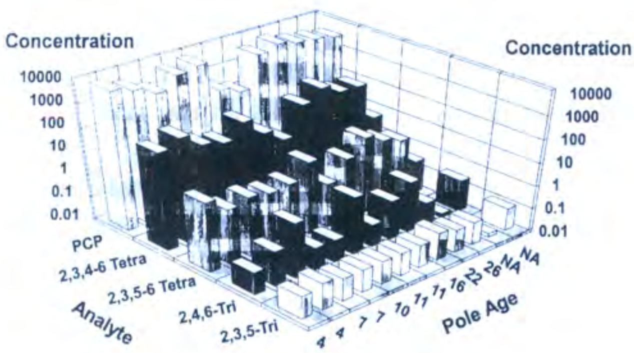



Fig. 5. Chlorophenols detected in wood samples (mg/kg).

## PCP in poles

Analyses of wood samples from representative poles show that PCP, two tetrachlorophenols and two trichlorophenols were detected (Fig. 5). The detected concentrations of PCP ranged from 260 to 9,500 mg/kg. Total tetrachlorophenols and trichlorophenols were found to range from 5.5 to 600.1 mg/kg and from no detection to 3.5 mg/kg, respectively. Pole age appears to have no effect on the level of chlorophenol in the wood sampled.

Technical grade PCP used for preservation should be 95% PCP (American Wood Preservers' Association 1995a). Tetrachlorophenols and trichlorophenols are present routinely in the preservative. The treatment solution is a dilution of the preservative. Typically, diesel fuel is the solvent (carrier) with which utility poles are treated. Using data from the literature and results from the New York pole study, Table 1 was prepared. Eisler (1989) (reported in O'Brien and Gere 1992) reported technical grade PCP to be 85–90% PCP. The total concentration of 2,3,4,6-tetrachlorophenol and 2,3,4,5-tetrachlorophenol varied between 40,000 and 80,000 milligrams per kilogram (mg/kg) and the total concentration of trichlorophenols was 1,000 mg/kg. Using the conventional, pressurized preservation treatment Standard C4 with preservative retention

**Table 1. Chlorophenol concentrations (mg/kg) in preservative, treated poles, in-service distribution poles, soil**

| Chlorophenol source | Pentachlorophenol | Total tetrachlorophenol | Total trichlorophenol |
|---|---|---|---|
| Technical grade[1] | 875,000 | 60,000 | 1,000 |
| Treated pole (calculated)[2] | 16,819 | 1,153 | 0.001 |
| In-service pole | 5,095 | 175[3] | 0.85[4] |
| Soil | 364 | 21[3] | 0.17[4] |

1. Average values from Eisler, 1989.
2. Based on retention of 0.45 $lbs/ft^3$ after treatment (American Wood Preservers' Association Standard C4).
3. Average totals of 2,3,4,6 tetrachlorophenol and 2,3,5 tetrachlorophenol for 10 poles.
4. Average totals of 2,4,6; 2,4,5; 2,3,4; 2,3,6; and 2,3,5 trichlorophenol for 7 poles.

of 0.45 $lb/ft^3$ (American Wood Preservers' Association 1995b), the theoretical concentrations of chlorophenols in freshly treated wood poles were calculated. Results from analyses of samples collected during the pole studies were used to calculate the average concentrations in wood and the average concentrations in the soil samples with the highest PCP concentration per pole. In comparing the calculated concentrations, it is evident that the relationship between PCP and total tetrachlorophenols was grossly similar across media. The relatively more reactive trichlorophenols did not show a consistent relationship to PCP and total tetrachlorophenols across all media. The changes in trichlorophenols for the theoretical calculations and the averages based on empirical measurement were consistent within each set of data. The breakdown of the penta and tetrachlorophenols could contribute to the variation in concentration of trichlorophenols overall.

The concentrations of PCP detected in soil near 10 New York poles tend to show similar relationships to PCP in the weathered pole with the exception of one pole (Table 2). Other comparisons could be made for tetrachlorophenols only. Overall, these relationships indicate a limited release of chlorophenols to the environment.

### Distribution of PCP

Results from the original (Fig. 6) and supplemental studies (Fig. 7) were similar in reference to the distribution of PCP with distance from poles. Pooled data from each study are presented to illustrate the contributions both made toward statewide characterization of the distribution of PCP around utility poles.

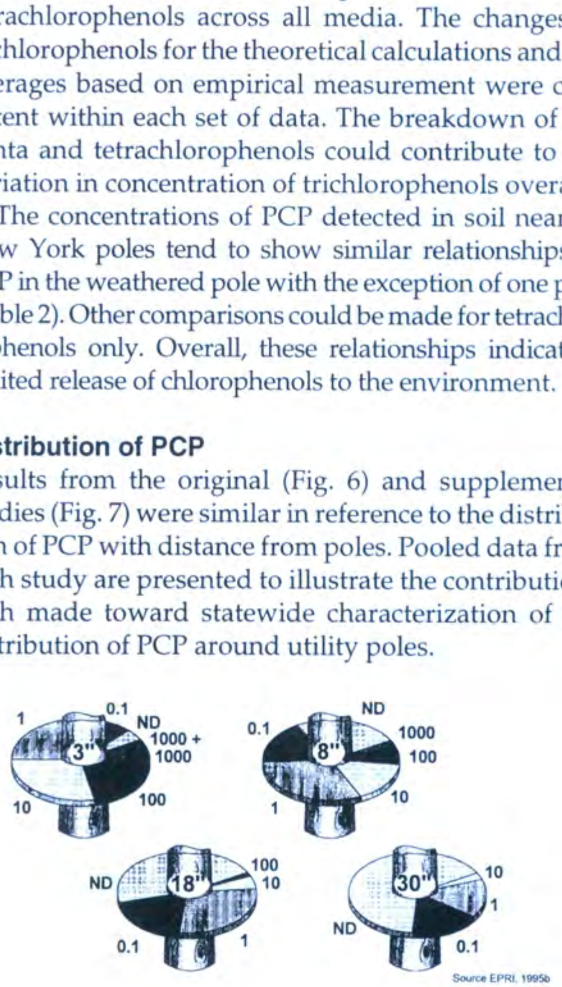



Fig. 6. Pooled distribution of PCP concentrations (mg/kg) by ring, for all depths (original study).

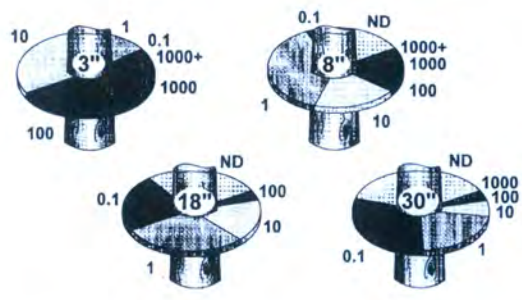



Fig. 7. Pooled distribution of PCP concentrations (mg/kg) by ring, for all depths (supplemental study).

**Table 2. Ratios of maximum chlorophenol concentration in soil samples[1] to concentration in individual wood samples (mg/kg)**

| Wood type | Pole age (years) | Pentachlorophenol in wood sample | Soil type | Ratio of soil to wood concentration | | |
|---|---|---|---|---|---|---|
| | | | | Pentachlorophenol | 2,3,5-6 Tetrachlorophenol | 2,3,4-6 Tetrachlorophenol |
| SP | 4 | 8,800[2] | S/C | 0.01 | 0.14 | 0.01 |
| SP | 7 | 6,860 J | W | 0.003 | 0.03 | 0.005 |
| SP | 7 | 2,300[2] | S | 0.08 | 0.02 | 0.08 |
| SP | 10 | 9,500[2] | S | 0.001 | 0.001 | NA |
| SP | 11 | 540[2] | S/C | 3.52 | 0.16 | 2.18 |
| SP | 11 | 260[2] | S/C | 0.11 | ND | 0.02 |
| SP | 22 | 8,440 | C | 0.01 | 0.01 | 0.01 |
| SP | 26 | 5,670 J | S/C | 0.02 | 0.04 | 0.01 |
| DF | 16 | 5,180 | S | 0.22 | 0.47 | 0.4 |
| WRC | N/A | 3,400[2] | S/C | 0.02 | ND | 0.19 |

1. The soil sample with the maximum level of pentachlorophenol near a pole (3-inch ring) for which wood concentration was measured was used for the comparison.
2. Source: EPRI (1995b).
NA = not analyzed; ND = not detected in soil samples; J = estimate.
Wood types: DF = Douglas Fir; SP = Southern Pine; WRC = Western Red Cedar.
Soil types: C = cobbly; S = sandy; S/C = silt/clay; W = wetland.

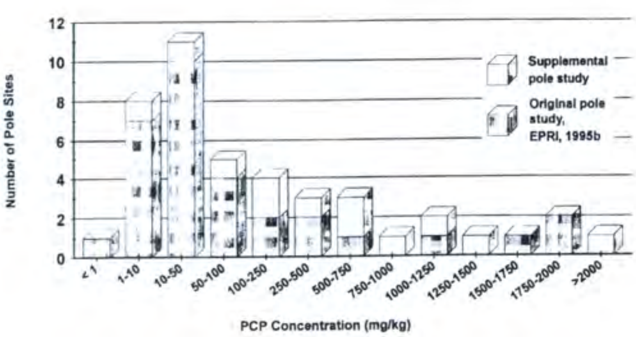



Fig. 8. Frequency histogram of maximum PCP concentrations in soil samples from wood pole sites.

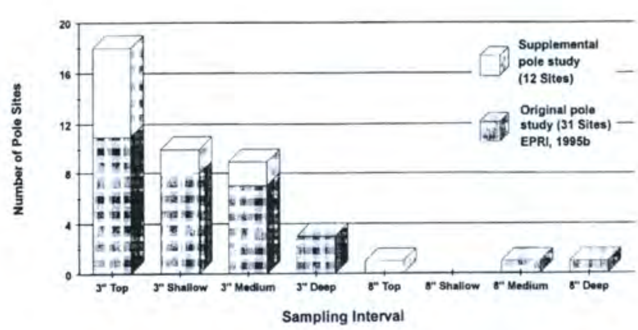



Fig. 9. Location of maximum soil PCP concentrations at pole sites.

Samples from the 7.6-cm (3-in) ring showed the widest range of concentrations, from < 0.1 to more than 1,000 mg/kg. Concentrations of PCP > 100 mg/kg were limited to the samples from the 7.6- and 20.3-cm (3- and 8-in) rings. More than half (25) of the maximum PCP concentrations in soil at each pole were <100 mg/kg (Fig. 8). The majority of maximum PCP concentrations per pole occurred within 0.9 m (3 ft) of the ground surface, in top (surface) and shallow samples (Fig. 9).

Secondary chlorophenols, while reduced in concentrations, showed generally similar patterns in distribution with distance from poles compared with PCP (Fig. 10). The maximum concentrations of quantified tetrachlorophenols and trichlorophenols appeared to mimic the distribution of maximum PCP.

Biodegradation of PCP, as represented by half-life (Fig. 11), was comparable for New York State and the United States; average half life of the PCP in laboratory studies was less than three years. The tendency for a longer half-life indicated by results for the Adirondack samples from the supplemental study corresponds with the tendency for higher concentrations and wider distribution of PCP in samples from the Adirondack area.

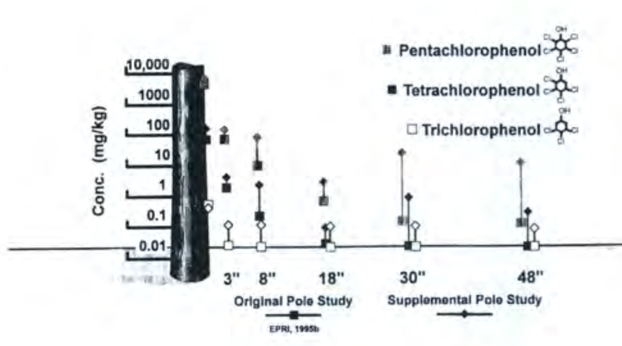



Fig. 10. Mean chlorophenol concentrations in soil and wood by distance from the pole.

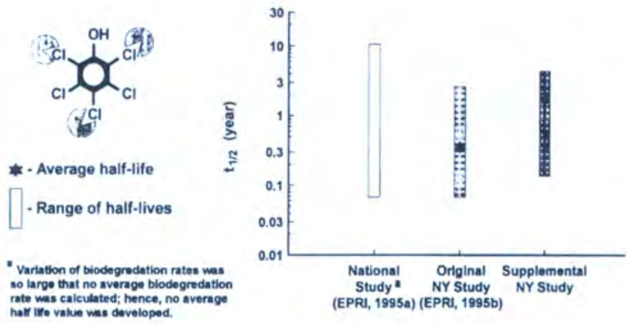



Fig. 11. Ranges of laboratory determined biodegradation half life ($t_{1/2}$) for PCP.

## Discussion

Multiple historic and current factors influence the distribution of PCP in soil near in-service wood poles. A relatively small part of a pole is underground. Typically, 1.5–1.8 m (5–6 ft) of a 12.2-m (40-ft) pole are buried; approximately 2.4 m (8 ft) of a 21.3-m (70-ft) pole. Therefore, most of the preserved pole is subject to weathering and associated leaching or "wash-off" due to precipitation. Wash-off from the aboveground part of the pole will encounter soil near the ground surface, producing high concentrations in soil within 7.6 cm (3 in) of the pole. PCP moves down the pole below ground and percolates through soil particles near the pole contribute to relatively high concentrations at depth within 7.6 cm (3 in).

Once present in the environment, the behavior of PCP is influenced highly by pH, which controls solubility in water. The organic content of soil and grain sizes are other strong influences on mobility of PCP via adsorption phenomena. Microbial populations in soil drive dechlorination processes, which result in degradation of PCP to simpler chlorophenols and ultimately to mineralization. All of these processes are influenced by the nature and movement of groundwater in the vicinity of the pole. On the molecular level, a dynamic condition exists in the vicinity of in-service utility poles; most of the activity is limited to short distances from the poles. At 45.7 cm (18 in) from New York poles, the concentrations of PCP in soil are much reduced from those 7.6 cm (3 in) away from poles.

Due to the sensitivity of PCP solubility to pH, soil pH is a major factor influencing the transport and fate of PCP in subsurface soil. In general, the pH of soil sampled during the supplemental study in the Adirondack region tended to be lower than for soil sampled during the first study, as expected, given the prominence of pine forest in the Adirondack area. Because solubility of PCP in water decreases as pH decreases, transport of PCP can be expected to decrease as well. The relative frequency of higher concentrations of PCP during the supplemental study, compared with the original study, is consistent with reduced mobility of PCP at low pH. The high frequency of samples with low PCP concentrations during the original study is consistent with greater mobility of PCP due to higher soil pH detected during the original study.

Approximately a third of the originally sampled poles (12) were located in comparatively fine-grained soil (silt/clay). Coarse materials, such as sand cobbles and till, were targeted during the supplemental study. The TOC levels measured during the original study tended to be greater than those measured during the supplemental study. These factors are consistent with the wider distribution of detectable PCP at poles sampled during the supplemental study. The reduced levels of TOC and generally wider pore space allow movement of PCP away from the poles.

This evidence developed during the New York pole studies documents the site specificity of the factors that influence the behavior of PCP in the vicinity of in-service utility poles. The success of preservation retention, climate and microbial populations are other important influences on the presence of PCP in soil. The dynamic prominence of the various influencing conditions combine to limit the presence of PCP in soil to short distances from each pole.

## REFERENCES

American Wood Preservers' Association. 1995a. Standards for oil-born preservatives, P8-95. In: Standards 1995. American Wood Preservers' Association, Woodstock, Maryland, pp. 12–13.

American Wood Preservers' Association. 1995b. C4-poles preservative treatment by pressure process. In: Standards 1995. American Wood Preservers' Association, Woodstock, Maryland, pp. 54–55.

Christodoulatos, C., G. Korfiatis, M. Talimcioglu, and M. Mohiuddin. 1994. Adsorption of pentachlorophenol by natural soils. Journal of Environmental Science Health–Environmental Science Engineering, A29(5): 883–898.

Eisler, R. 1989. Pentachlorophenol hazards to fish, wildlife and invertebrates: A synoptic review. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 85: (1.17).

Electric Power Research Institute. 1993. Biodegradability of pentachlorophenol in the environment: A literature review. Electric Power Research Institute, Pleasant Hill, California, TR-102172.

Electric Power Research Institute. 1995a. Interim report on the fate of wood preservatives in soils adjacent to in-service utility poles in the United States Electric Power Research Institute, Pleasant Hill, California, EPRI TR-104968.

Electric Power Research Institute. 1995b. Pentachlorophenol (PCP) in soils adjacent to in-service utility poles in New York State. Electric Power Research Institute, Pleasant Hill, California, EPRI TR-104893.

Federal Register. 1990. Vol. 55, No. 61, 29 March.

Lafrance, P., L. Marineau, L. Perreault, and J.P. Villeneuve. 1994. Effect of natural dissolved organic matter found in groundwater on soil adsorption and transport of pentachlorophenol. Environmental Science and Technology, 28(13): 2314–2320.

Mortimer, W. 1991. The environmental persistence and migration of wood preservatives. Ontario Hydro Research, Toronto, 103 pp.

O'Brien and Gere. 1992. Pentachlorophenol in wood utility poles: Environmental fate and toxicology. Empire State Electric Energy Research Corporation/Electric Power Research Institute, Altamont, New York, 190 pp.

---

## *BIOGRAPHICAL SKETCHES*

***Edward F. Neuhauser***

*Niagara Mohawk Power Corporation, 300 Erie Boulevard West, Syracuse, NY 13202, USA*

Dr. Edward F. Neuhauser, a Senior Research Specialist at Niagara Mohawk Power Corporation (NMPC), received his Ph.D. in soil biology from the SUNY School of Environmental Science and Forestry in Syracuse, New York. Post-doctoral research was on biodegradation and land treatment of oily wastes. At NMPC, Dr. Neuhauser is responsible for development and management of renewable and energy storage programs and the environmental and safety programs. He has been involved with projects on wood preservative leaching, remediation of former manufactured gas plant (MGP) sites, wind turbine technology, movement of metals through ecosystems, and zebra mussels. He is a member of the Land and Water Quality Studies Science Advisory Committee and participates on various task forces and review panels for the Electric Power Research Institute (EPRI), Edison Electric Institute (EEI), and the Gas Research Institute (GRI).

***Ishwar P. Murarka***

*Electric Power Research Institute, Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94303, USA*

Dr. Ishwar Murarka leads the Land and Water Quality business area at the Electric Power Research Institute (EPRI). Initial research focused on metals and inorganics, leading to state-of-the-art publications on coal ash leaching, attenuation, and migration. Research broadened to include organic compounds and complex mixtures. Major advances have been made in research on contaminated soils, surface and groundwater assessment, protection and restoration/remediation. Before joining EPRI in 1979, Dr. Murarka was an Environmental Scientist at Argonne National Laboratory. He received an M.A. degree in Geography from Calcutta University. He earned M.A. and Ph.D. degrees from Oregon State University in Soil Science and Statistics; he holds an M.B.A. from the University of Chicago. A Certified Professional Soil Scientist (CPSS) since 1984, Dr. Murarka is Chairman of the U.S. Environmental Protection Agency's Environmental Engineering Committee and is a member of the Executive Committee of the Science Advisory Board. He is a member of the Advisory Board of the Journal of Soils dealing with analysis, monitoring, and remediation. He has served on the Council for Agricultural Science and Technology (CAST) Board of Directors and on a Committee of the National Research Council.

***Scott Shupe***

*Niagara Mohawk Power Corporation, 300 Erie Boulevard West, Syracuse, NY 13202, USA*

Scott D. Shupe, Environmental Analyst at Niagara Mohawk Power Corporation, holds a BS in Biology and an MS in Water Resource Management from SUNY College of Environmental Science and Forestry, and an MS in Science Management from the University of Alaska-Anchorage. His career has spanned the planning–construction—operations spectrum, including high-voltage powerline construction management, small hydropower and navigation planning, and is currently supporting non-nuclear generation, gas, and electric system operating and licensing groups.

***Martha Mayer***

*GEI Consultants, Inc., Atlantic Environmental Division, 188 Norwich Avenue, Colchester, CT 06415, USA*

Martha M. Mayer is a principal scientist with Atlantic Environmental. She received an MS in Fisheries Sciences from Texas A&M University and has 25 years of experience addressing environmental questions for electric utilities, including power-plant siting and operation, right-of-way selection, and site investigation/remediation. Ms. Mayer directed the supplemental New York pole study for Niagara Mohawk Power Corporation and is currently conducting a life-cycle analysis of preserved transmission and distribution poles.

# Symposium participants


Lawrence Abrahamson
*State University of New York*
*1 Forestry Drive*
*Syracuse, NY 13210, USA*

Boyd Allen
*Foster Wheeler*
*470 Atlantic Avenue*
*Boston, MA 02210, USA*

Paul Anderson
*Golder Associates Ltd.*
*1011 Sixth Ave. SW*
*Calgary, Alberta, Canada T2P OW1*

Ted Anderson
*Western Area Power Administration*
*P.O. Box 58000, 2900 4th Avenue*
*Billings, MT 59101, USA*

John Anderson
*North Carolina State University*
*P.O. Box 7620*
*Raleigh, NC 27695-7620, USA*

Tim Anderson
*Natural Resource Group, Inc.*
*1800 International Center, 90 2nd Ave. S.*
*Minneapolis, MN 55402, USA*

Jim Arndt
*Peterson Environmental Consulting*
*1355 Mendota Heights*
*St. Paul, MN 55120, USA*

Dale Arner
*Mississippi State University*
*209 Seville Place*
*Starkville, MS 39759, USA*

Robert Arvedlund
*Federal Energy Regulatory Commission*
*2303 Dexter Avenue*
*Wheaton, MD 20909, USA*

Lynn Askew
*Power Engineers, Inc.*
*P.O. Box 1066*
*Hailey, IN 83333, USA*

Lee Atkins
*Timberland Enterprises, Inc.*
*P.O. Box 267*
*Natchez, MS 39121, USA*

John Bankston
*Entergy Services, Inc.*
*P.O. Box 1640*
*Jackson, MS 39042, USA*

Tim Barnes
*Iroquois Gas Transmission System*
*One Corporate Drive, Suite 600*
*Shelton, CT 06484, USA*

Rex Bartlett
*Allegheny Power*
*800 Cabin Hill Drive*
*Greensburg, PA 15601, USA*

Aaron Bass
*8791 Sharlane Drive*
*Baton Rouge, LA 70809, USA*

Lisa Beal
*Interstate Natural Gas Association of America*
*555 13th St. NW, Suite 300*
*Washington, DC 20004, USA*

Mark Beamish
*Orange & Rockland Utilities*
*500 Route 208*
*Monroe, NY 10950, USA*

Joseph Beaudoin
*Columbia Gas*
*525 Highlands Blvd., Suite 100*
*Coatesville, PA 19365, USA*

Anthony Becker
*The National Faculty*
*200 Carondelet Street, Suite 1700*
*New Orleans, LA 70130-2900, USA*

Jeff Beckwith
*Puget Sound Energy*
*600 116th Avenue NE*
*Bellevue, WA 98004, USA*

Yves Bedard
*Transport Quebec*
*5353 Pierre-Bertrand*
*Quebec, Canada G2K 1M1*

Edward Beene
*B&H Environmental Services, Inc.*
*811 Dallas 7th Floor*
*Houston, TX 77002, USA*

G.J. (Hans) Bekker
*Ministry of Transport*
*P.O. Box 5044*
*2600 GA Delft, The Netherlands*

Bob Bell
*PNM Electric Services*
*4201 Edith Blvd. NE*
*Albequerque, NM 87107, USA*

Celine Belzile
*Hydro Quebec*
*800 Boulevard de Maisonneuve*
*Montreal, Quebec, Canada H2L 4M8*

Mark Bisett
*3D International*
*1900 W. Loop South, Suite 400*
*Houston, TX 77027-3292, USA*

Michelle Bissonnette
*Braun Interte*
*1345 Northland Drive*
*Mendota Heights, MN 55120-1141, USA*

Denis Blais
*Phenix Environmental, Inc.*
*30 Broadway, Suite 207*
*Kingston, NY 12401, USA*

Roberta Blue
*Carolina Power & Light Co.*
*932 New Hill-Holleman Rd., Box 327*
*New Hill, NC 27562-0327, USA*

Bill Bonner
*Electric Power Research Institute*
*3010 LBJ, Suite 300*
*Dallas, TX 75234, USA*

David Bouchard
*Central & Southwest Services, Inc.*
*1616 Woodall Rodgers Freeway*
*Dallas, TX 75202, USA*

Andre Bouchard
*Université de Montreal*
*4101 Est. Sherbrooke Street*
*Montreal, Quebec, Canada H1X 2B2*

John Bowen
*Ontario Hydro*
*935 Power Street*
*London, Ontario, Canada N5Z 1A1*

Michael Boyle
*Federal Energy Regulatory Commission*
*888 1st Street NE, Room 72-50*
*Washington, DC 20426, USA*

Deborah Boyle
*Texas Utilities Services Co.*
*1601 Bryan Street*
*Dallas, TX 75201, USA*

David Bradley
*Pacific Gas & Electric*
*Mail Code 812A, P.O. Box 770000*
*San Francisco, CA 94177, USA*

Gary Breece
*The Southern Company*
*270 Peachtree Street NW, Suite 2100*
*Atlanta, GA 30303, USA*

John Bridges
*Western Area Power Administration*
*P.O. Box 3402*
*Golden, CO 80401, USA*

Gary Brinston
*Newfoundland & Labrador Hydro*
*P.O. Box 2002*
*Bishops Falls, Newfoundland, Canada AOH 1CO*

Jacques Brisson
*Université de Montreal*
*4101 EST, Sherbrooke Street*
*Montreal, Quebec, Canada H1X 2B2*

Robert Brocksen
*Electric Power Research Institute*
*2000 L Street N.W., Suite 805*
*Washington, DC 20036, USA*

Paul Brown
*Natural Gas Pipeline Co. of America*
*701 East 22nd Street*
*Lombard, IL 60148-5072, USA*

Josee Brunelle
*Foramec, Inc.*
*70 Rue Saint-Paul*
*Quebec, Quebec, Canada G1K 3V9*

Allan Burdett
*Transpower New Zealand*
*P.O. Box 1021*
*Wellington, New Zeland*

Mario Buszynski
*Jacques Whitford Environment Ltd.*
*85 Citizen Court, Unit 18*
*Toronto, Ontario, Canada L6G 1A7*

Bernarlita Cadinas
*Interconexion Electrica S.A.*
*21 Old Farms Lane*
*Cazenovia, NY 13035, USA*

Nancy P. Cain
*Ministry of Transportation*
*R&D Branch, 1201 Wilson Avenue,*
*Room 331 CB*
*Downsview, Ontario, Canada M3M 1J8*

Carl Calfo
*Penn Line SVC. Inc.*
*P.O. Box 462*
*Scottdale, PA 15683, USA*

Bernardita Calino
*Interconexion Electrica S.A.*
*21 Old Farms Lane*
*Cazenovia, NY 13035, USA*

Denise Campbell
*Potomac Electric Power Co.*
*1900 Pennsylvania Ave. NW, Room 710*
*Washington, DC 20068, USA*

W.J. Candler
*Georgia Power Company*
*5131 Maner Road*
*Smyrna, GA 30080, USA*

Helene Chaisson
*Le Groupe H.C.*
*10625 Des Prairies*
*Montreal, Canada H2B 2K7*

Kevin Chatelain
*Dupont AG Producers*
*415 Lasalle Drive,*
*Little Rock, AR 72211, USA*

Nick Chevance
*Western Area Power Admn.*
*P.O. Box 3402*
*Golden, CO 80401, USA*

Timothy Chick
*Consultant*
*844 Fairlane Court #6*
*Saginaw, MI 48609, USA*

Steven Christiansen
*Asplundh Tree Service Inc.*
*P.O. Box 3000*
*Dartmouth, Nova Scotia, Canada B2W 4Y3*

Cheryl Cobb
*664 Longwood Circle*
*Auburn, AL 36830, USA*

Lora Cocco
*Electric Power Research Institute*
*3412 Hill View Avenue*
*Palo Alto, CA 94304-1395, USA*

William Coleman
*Electric Power Research Institute*
*3412 Hill View Avenue*
*Palo Alto, CA 94304-1395, USA*

Bob Collier
*Asplundh*
*1900 Betson Court*
*Odenton, MD 21113, USA*

Ken Colosimo
*National Energy Board Canada*
*311 6th Avenue S.W.*
*Calgary, Alberta, Canada T2P 3H2*

Edward Colson
*Colson & Associates*
*9 Corwin Drive*
*Alamo, CA 94507, USA*

Jeff Colwell
*P.O. Box 3288*
*Tulsa, OK 74101, USA*

Brad Condley
*East Kentucky Power Cooperative*
*P.O. Box 707*
*Winchester, KY 40391, USA*

Morgan Corvill
*3300 University Avenue SE*
*Minneapolis, MN, USA*

Allen Crabtree
*Resource Management International*
*1850 Domig Road*
*Rescue, CA 95672, USA*

Patricia Crane
*Tacoma Public Utilities*
*P.O. Box 11007, 1215 160th Street CT. E.*
*Tacoma, WA 98411, USA*

Ray Cummings
*Niagara Mohawk Power Corp.*
*300 Erie Blvd. West*
*Syracuse, NY 13202, USA*

David Daugherty
*Global Management Services*
*5807 Quail Hollow Circle*
*Chattanooga, TN 37416, USA*

Esteban Davila
*Interconexion Electrica*
*Calle 200 Correra 8*
*Sante Fe, Bogota, Columbia*

Danny Davis
*Baltimore Gas & Electic*
*7152 Windsor Blvd.*
*Baltimore, MD 21244, USA*

John Davis
*Evergreen Helicopters*
*2001 Terminal Drive*
*Galveston, TX 77554, USA*

Jim Davis
*Electric Power Research Institute*
*3412 Hill View Avenue*
*Palo Alto, CA 94304-1395, USA*

Leslie Degner
*Transco*
*2800 Post Oak Blvd.*
*Houston, TX 77503, USA*

Amy Dierolf
*Florida Power Corp.*
*P.O. Box 14042 (H2G)*
*St. Petersburg, FL 33733, USA*

Steve Dixon
*Louisville Gas & Electric Company*
*P.O. Box 32010*
*Louisville, KY 40232, USA*

Clayton Doherty
*Oglethorpe Power*
*P.O. Box 1349*
*Tucker, GA 30085, USA*

Jean Domingue
*Naturam Environnement*
*31 Marquette*
*Baie Comeau, Quebec, Canada G42 1K4*

Kevin Dominske
*Phenix Environmental, Inc.*
*P.O. Box 613*
*Boonville, NY 13309-0613, USA*

Paul Dorion
*Canadian Pacific Railway*
*P.O. Box 6042, Room 430*
*Montreal, Quebec, Canada H3C 3E4*

G. Jean Doucet
*Hydro-Quebec*
*75, Boul. Rene-Levesque Ouest, 16E Etage,*
*Montreal, Quebec, Canada H2Z 1A4*

Joy Drach
*705 Cherokee Lane*
*Pontiac, IL 61764, USA*

Reinhard Draxler
*Graz University of Technology*
*Inffeldgusse 18*
*Graz A-8010, Austria*

Suzanne Dupuis
*Aluminum Company of America*
*100 St. Joseph #104*
*Alma, Quebec, Canada G8B 5V6*

Dan Eddy
*Midland Vegetation Mgt., Inc.*
*P.O. Box 3448*
*Regina, Saskatchewan, Canada S4P 3J8*

Colin Edey
*Nova Gas Transmission Ltd*
*P.O. Box 2535 Station M*
*Calgary, Alberta, Canada T2P 2N6*

Robert Ehrler
*Louisville Gas & Electric Co.*
*P.O. Box 32010*
*Louisville, KY 40232, USA*

Kevin Ellis
*Nova Gas Transmission*
*P.O. Box 2535 Station M*
*Calgary, Alberta, Canada T2P 2N6F*

Bill Erickson
*Bonneville Power Administration*
*1520 Kelly Place*
*Walla Walla, WA 99352, USA*

Jimmy Etheridge
*Georgia Power Co.*
*960 Key Street*
*Macon, GA 31204, USA*

James Evans
*Gas Research Institute*
*8600 W. Bryn Hawk*
*Chicago, IL 60631, USA*

Kenneth Farrish
*Steven F. Austin State University*
*College of Forestry*
*Nacogdoches, TX 75961, USA*

Al Fedkenheuer
*Nova Gas Transmission Ltd.*
*P.O. Box 2535, Station M*
*Calgary, Alberta, Canada T2P 2N6*

Larry Ferrandiz
*Long Island Lighting Co.*
*1615 Ilsip Avenue*
*Brentwood, NY 11717, USA*

Ron Fields
*Public Service Co. New Mexico*
*Alvarado Square*
*Albuquerque, NM 87158, USA*

Kennith Finch
*Niagara Mohawk Power Corp.*
*300 Erie Blvd. W.*
*Syracuse, NY 13202, USA*

Scott Fletcher
*Northrop Devine*
*500 Washington Avenue*
*Portland, ME 04102, USA*

Antonio Fonseca dos Santos
*Companhia Paranaense de Energia-Brazil*
*Rua Padre Anchieta 30 AP42*
*Curitiba Parana, Brazil 80410-030*

David Frantz
*Columbia Gas Transmission Corp.*
*P.O. Box 1273*
*Charleston, WV 25325, USA*

Michel Galet
*Cofiroute France*
*La Vente aux Moines*
*Saran F-45770, France*

Yves Garant
*Naturam Environnement*
*31 Marquette*
*Baie-Comeau, Quebec, Canada G42 1K4*

Julia Gaskin
*Earth Systems Associates, Ltd.*
*1013 S. Milledge Avenue*
*Athens, GA 30605, USA*

Francois Gautheir
*Hydro-Quebec*
*750 Rene Leuesque 16th*
*Montreal, Quebec, Canada H2Z 1A4*

Joe Giammalva
*Entergy Services, Inc.*
*P.O. 61000*
*New Orleans, LA 70161, USA*

Jodean Giese
*Dept. of Water & Power Los Angeles*
*111 N. Hope Street, Room 1121*
*Los Angeles, CA 90012, USA*

Michel Giguere
*Hydro-Quebec*
*75 Boul Rene-Levesque O, 16th Fl.*
*Montreal, Quebec, Canada H2Z 1A4*

Lloyd Gilmore
*Entergy Services, Inc.*
*P.O. Box 1640*
*Jackson, MS 39215, USA*

Philip Gizzi
*New York Power Authority*
*P.O. Box 200*
*Gilboa, NY 12076, USA*

John Goodrich-Mahoney
*Electric Power Research Institute*
*Suite 805, 2000 L Street NW*
*Washington, DC 20036, USA*

Steven Grandinali
*Orange & Rockland Utilities*
*500 Route 208*
*Monroe, NY 10950, USA*

Scott Gravatt
*Potomac Electric Power Co.*
*1900 Pennsylvania Avenue NW, Room 202-Benn.*
*Washington, DC 20068, USA*

Susan Gray
*Idaho Power*
*P.O. Box 70*
*Boise, ID 83707, USA*

Dan Gredvic
*Colorado Interstate Gas Co.*
*P.O. Box 1465*
*Rawlins, WY 82301, USA*

Mark Gumbert
*East Kentucky Power Co.*
*976 Villa Drive #10*
*Richmond, KY 40475, USA*

David Hagen
*Essex Environmental*
*751 Kelly Avenue*
*Half Moon Bay, CA 94019, USA*

Richard Hall
*Columbia Gas Transmission Corp*
*1700 Maccorkle Avenue*
*Charleston, WV 25325, USA*

Osmo Haltia
*Ministry of Trade Finland*
*Kauppa Pl 230*
*Helsinki 00171-17, Finland*

Bonnie Harper-Lore
*Federal Highway Administration*
*US Dept. Transportation, 490 Metro Square Bldg.,*
*St. Paul, MN 55101, USA*

Richard Harrell
*Cinergy*
*139 East 4th Street*
*Cincinatti, OH 45202, USA*

Hubert Harrell
*One Corporate Drive*
*Suite 600*
*Shelton, CT 06484, USA*

Zig Hathorn
*British Columbia Hydro*
*6911 Southpoint Drive*
*Burnaby, British Columbia, Canada V3N 4X8*

Tom Hayes
*East Kentucky Power Cooperative, Inc.*
*P.O. Box 707*
*Winchester, KY 40391, USA*

Howard Heffler
*Alliance Pipeline*
*605 5th Avenue SW, Suite 400*
*Calgary, Alberta, Canada T2P 3H5*

Leslie Helleher
*Bonneville Power Administration*
*1520 Kelly Place*
*Walla Walla, WA 99352, USA*

Tammy Henry
*Entergy Services, Inc.*
*5115 Thibault Rd.*
*Little Rock, AR 72206, USA*

Alton Higgins
*Central Hudson Gas & Electric*
*284 South Avenue*
*Poughkeepsie, NY 12601, USA*

J. Parker Hill
*Santee Cooper*
*One Riverwood Drive*
*Monchs Corner, SC 29461, USA*

Samuel Hogg
*Alabama Electric Coop*
*P.O. Box 550*
*Andalusia, AL 36420, USA*

Jeff Hohman
*East Kentucky Power*
*P.O. Box 707*
*Winchester, KY 40391, USA*

Harvey Hol
*Purdue University*
*Dept. of Forestry*
*West Lafayette, IN 47907-1159, USA*

Robert Honig
*Tenneco Energy*
*3803 Purdue*
*Houston, TX 77005, USA*

Steve Hoover
*Entergy Services, Inc.*
*P.O. Box 61000*
*New Orleans, LA 70161, USA*

Patty Hoppe
*Entergy Services, Inc.*
*P.O. Box 61000*
*New Orleans, LA 70161, USA*

Daniel Hushion
*Alliance Pipeline*
*605 5th Avenue SW, Suite 400*
*Calgary, Alberta, Canada T2P 3H5*

C.R. (Randy) Isbell
*Georgia Power Company*
*1450 Atlanta Road*
*Marietta, GA 30060, USA*

Catharinus Jaarsma
*Wageningen Agricultural University*
*Gen. Foulkesweg 13*
*NL-6703 EC Wageningen, Netherlands*

Lawrence Jackson
*New York State Dept. of Public Service*
*54 High Point Road*
*Berne, NY 12023, USA*

David Jenkins
*Foster Wheeler Environmental*
*470 Atlantic Avenue 3rd Floor*
*Boston, MA 02210, USA*

Raymond Jewett
*Vermont Gas Systems, Inc.*
*P.O. Box 467*
*Burlington, VT 05402, USA*

Byron Johnson
*United Power Associates*
*P.O. Box 800*
*Elk River, MN 55330, USA*

Chris Johnson
*Western Area Power Administration*
*P.O. Box 3402*
*Golden, CO 80401, USA*

Christy Johnson
*Oglethorpe Power*
*P.O. Box 1349*
*Tucker, GA 30085-1349, USA*

Fred Johnson
*Bonneville Power Administration*
*P.O. Box 491*
*Vancouver, WA 98686, USA*

Chris Johnson
*Department of Energy*
*114 Parkshore Drive*
*Folson, CA 95630, USA*

Melvin Johnson
*Purdue University*
*1159 Forestry Bldg.*
*West Lafayette, IN 47907-1159X, USA*

Richard Johnston
*Delmarva Power*
*P.O. Box 1739*
*Salisbury, MD 21802-1739, USA*

Conrad Journault
*Transalta Utilities*
*110 12 Avenue SW*
*Calgary, Alberta, Canada T2P 2M1*

Steve Kartalia
*Versar, Inc.*
*9200 Ramsey Road*
*Columbia, MO 21045, USA*

Jon Keener
*Com Ed Environmental Services*
*Box 767*
*Chicago, IL 60690, USA*

Dean Keith
*Williams Natural Gas Co.*
*P.O. Box 3288, Floor Zone 31-7*
*Tulsa, OK 74101, USA*

Leslie Kelleher
*Bonneville Power Administration - ECN*
*P.O. Box 3621*
*Portland, OR 97208, USA*

Nhu-Uyen "Winn" Khuong
*American Cyanamid*
*One Campus Drive*
*Parsippany, NJ 07054, USA*

Norman Kinsella
*Entergy Services, Inc.*
*P.O. Box 2431*
*Baton Rouge, LA 70821, USA*

Greg Kirchmayer
*Entergy Services, Inc.*
*20955 Old Scenic Hwy.*
*Zachary, LA 70791, USA*

Adam Klatzker
*Thomas Olsen Associates*
*136 N. Celilo*
*Flagstaff, AZ 86001, USA*

Andria Kline, Jr.
*110 Miller*
*Ann Arbor, MI 48104, USA*

Paul Kolenick
*Sask Power Environmental Programs*
*3NE-2025 Victoria Avenue*
*Regina, Saskatchewan, Canada J4P 3Y8*

James Kondikoff
*GPU Energy*
*2121 Sullivan Trail*
*Easton, PA 18040, USA*

Gayle Konik
*Great Lakes Gas Transmission*
*One Woodward Avenue*
*Detroit, MI 48226, USA*

Jerry Koonce
*Columbia Gas Transmission*
*301 Maple Street*
*Sugar Grove, OH 43155, USA*

Mark Korn
*Allegheny Power*
*800 Cabin Hill Drive*
*Greensburg, PA 15601, USA*

Stephen Krotzer
*Alabama Power Company*
*P.O. Box 2641*
*Birmingham, AL 35291, USA*

Kathy Kunkel
*GPU Energy*
*P.O. Box 16001, 2800 Pottsville Pike*
*Reading, PA 19640-0001, USA*

Lasse Kylakorpi
*Vattenfall Utveckling AB*
*Stockholm S-16287, Sweden*

Marc Lapointe
*Bell Canada*
*87 Ontario W #525*
*Montreal, Quebec, Canada H2X 148*

Ernest Ladkani
*B&H Environmental Services, Inc.*
*811 Dallas Street, 7th Fl.*
*Houston, TX 77002, USA*

Chae Laird
*Southern Natural Gas*
*P.O. Box 2563*
*Birmingham, AL 35202-2563, USA*

Maryse Lambert
*Hydro Quebec Environment Dept.*
*75 Rene Levesque West, 16th Floor*
*Montreal, Quebec, Canada H2Z 1A4*

Harlow Landphair
*Texas Transportation Institute*
*707 Texas Avenue S., Suite 100*
*College Station, TX 77843, USA*

John Lassiter
*Oglethorpe Power Company*
*2100 E. Exchange Place*
*Tucker, GA 30385, USA*

Chad Leblanc
*U.S. Fish & Wildlife Services*
*2314 Koliste Saloon #608*
*Lafayette, LA 70508, USA*

Carl Lemmer
*Wisconsin Gas*
*5400 North Green Bay Avenue*
*Milwaukee, WI 53209, USA*

Claude Lewis
*Tennessee Valley Authority*
*1101 Market Street MR5K*
*Chattanooga, TN 37402, USA*

Victor Lewynsky
*British Columbia Hydro*
*1340 Holamolha Lake Road*
*Vernon, British Columbia, Canada V1T 6L1*

Steven Lindenberg
*Electric Power Research Institute*
*2000 L Street NW*
*Washington, DC 22031, USA*

Donna Lindquist
*Natural Resource Group, Inc.*
*2303 Camino Ramon, Suite 200*
*San Ramon, CA 94583, USA*

Andy Linehan
*CH2M Hill*
*825 Nemohnorrah, Suite 1300*
*Portland, OR 97232, USA*

Chris Longinotti
*Entergy Services, Inc.*
*P.O. Box 551*
*Little Rock, AR 72203, USA*

Scott Lounsbury
*Lakehead Pipeline Co*
*2100 Superior Street*
*Duluth, MN 55802-2067, USA*

Stuart Lunn
*Pan Canadian Petroleum Limited*
*150 9th Avenue SW*
*Calgary, Alberta, Canada T2P 2S5*

David Macks
*New York State Dept. of Public Service*
*3 Empire State Plaza*
*Albany, NY 12223, USA*

Sid Mayo
*Entergy Services, Inc.*
*P.O. Box 1640*
*Jackson, MS 39215, USA*

Joel Mazelis
*Edison Electric Institute*
*701 Pennsylvania Avenue NW*
*Washington, DC 20006, USA*

Scott McCollough
*Grant County Public Utility District*
*P.O. Box 878*
*Ephrata, WA 98823, USA*

John McCullough
*KEA Environmental*
*455 University Ave., Suite 370*
*Sacramento, CA 95825, USA*

Ian McDonald
*Ace Vegetation*
*Bay A, 2001 8 Street*
*Nisku, Alberta, Canada T9E 7Z1*

Bob McElfresh
*Cinergy Corp.*
*139 E. 4th Street, Room 552-A*
*Cincinnati, OH 45202, USA*

Jack McGee
*Idaho Power Co.*
*P.O. Box 70*
*Boise, ID 83705, USA*

Rita McKenzie
*Purdue University*
*1159 Forestry Bldg.*
*West Lafayette, IN 47907-1159X, USA*

Gus McLachlan
*Algonquin Gas Transmission Co.*
*1284 Soldiers Field Road*
*Boston, MA 02135, USA*

Kevin McLoughlin
*New York Power Authority*
*New York Power Pool Annex*
*Altamont, NY 12009, USA*

Joseph McMullen
*Terrestrial Environmental Specialists Inc.*
*23 Country Route 6, Suite A*
*Phoenix, NY 13135, USA*

Alain Meilleur
*Université de Montreal*
*4101 Est. Sherbrooke Street*
*Montreal, Quebec, Canada H1X 2B2*

Hugh Merriam
*Pacific Gas & Electric*
*303 Carlson Street*
*Vallejo, CA 94950, USA*

Timothy Messick
*Alabama Electric Cooperative Inc.*
*P.O. Box 550, Hwy. 29 N.*
*Andalusia, AL 36420, USA*

Rachelle Michelis
*Cyanamid*
*One Campus Drive*
*Parsippany, NJ 7960, USA*

Richard Mider
*New York State Electric & Gas Corp.*
*P.O. Box 5224*
*Binghampton, NY 13902-5224, USA*

Clyde Modre
*International Bourdeux Commission*
*1250 23rd St. NW, Suite 100*
*Washington, DC, 20037, USA*

Rich Mogensen
*Transco*
*P.O. Box 1396*
*Houston, TX 77251, USA*

Eric Mohun
*Gartner Lee*
*6400 Roberts St., Suite 490*
*Burnaby, British Columbia, Canada*
*V5G 4C9*

Shirley Morrow
*Burns & McDonnel, Inc.*
*9400 Ward Parkway*
*Kansas City, MO 64114, USA*

Johan Mortier
*CPTE - Belgium*
*Rue de Rhode, 125*
*Linkeek B-1630, Belgium*

Ishwar Murarka
*Electric Power Research Institute*
*3412 Hill View Avenue*
*Palto Alto, CA 95014, USA*

Thomas Murphy
*Bonneville Power Administration*
*707 W. Main, Room 500*
*Spokane, WA 99201, USA*

Frank Muschalla
*Bell Canada*
*2 Fieldway Road Floor 10B*
*Etobicoke, Ontario, Canada M82 3L2*

Dean Mutrie
*Terra Environmental Consultants*
*4512-25 Ave. SW*
*Calgary, Alberta, Canada T2P 1A5*

Ted Nelson
*Nelson Consulting, Inc.*
*P.O. Box 5556*
*Farmington, NM 87401, USA*

Edward Neuhauser
*Niagara Mohawk Power Corp.*
*300 Erie Blvd. W.*
*Syracuse, NY 13202, USA*

Deanne Newkirk
*Sask Power*
*2025 Victoria Avenue*
*Regina, Saskatchewan, Canada S4P 0S1*

Wilford Nez
*Public Service Company New Mexico*
*Alvarado Square*
*Albuquerque, NM 87158, USA*

Logan Norris
*Oregon State University*
*Department of Forest Science F-5L 020*
*Corvallis, OR 97331, USA*

Craig Nyrose
*Alberta Power Limited*
*9717-97 Avenue*
*Grande Prairie, Alberta, Canada T8V 6L9*

Chuck Olenik
*GPU Energy*
*501 Parkway Blvd.*
*York, PA 17404, USA*

William Oneal
*Entergy*
*Baton Rouge, LA, USA*

James Orr
*Asplundh*
*708 Blair Mill Road*
*Willow Grove, PA 19090, USA*

John Osinski
*New York Power Authority*
*99 Washington Avenue, Suite 1950*
*Albany, NY 12210, USA*

Erkki Partanen
*IVO Transmission Services*
*Pl. 629*
*Helsinki 00101, Finland*

Patricia Patterson
*Foster Wheeler Environmental*
*470 Atlantic*
*Boston, MA 02210, USA*

Dan Pearson
*Southern California Edison*
*P.O. Box 800*
*Rosemead, CA 91770, USA*

Harold Pellett
*Minnesota Landscape Arboretum*
*1450 Game Farm Road N.*
*Mound, MN 55364, USA*

Jerome Perez
*COMED*
*29 Primrose Lane*
*Sycamore, IL 60178, USA*

Matthew Perry
*Patuxent Wildlife Research Center*
*11410 American Holly Dr.*
*Laurel, MD 20708, USA*

Carol Peters
*Arizona Electric Power Cooperative*
*P.O. Box 670*
*Benson, AZ 85602, USA*

Ronald Peterson
*Peterson Environmental Consulting*
*1355 Mendota Heights*
*St. Paul, MN 55120, USA*

Ralph Peterson
*Entergy Services, Inc.*
*P.O. Box 551*
*Little Rock, AR 72203, USA*

Brenda Powell
*Ecology & Environment, Inc.*
*1950 Commonwealth Lane*
*Tallahassee, FL 32303, USA*

Richard Precek
*Plains Electric Generation*
*P.O. Box 6551*
*Albuquerque, NM 87197, USA*

Robert Preston
*Evergreen Helicopters*
*112 Danya Drive*
*Prattville, AL 36067, USA*

Peter Prier
*Ecological Services Group*
*361 Southgate Drive*
*Guelph, Ontario, Canada N1G 3M5*

Brian Provo
*Nova Gas Transmission*
*P.O. Box 2535, Station M*
*Calgary, Alberta, Canada T2P 2N6*

Sam Quattrochi
*Dow Elanco*
*873 Heritage Hills Drive*
*York, PA 17402, USA*

Adda Quinn
*Electric Power Research Institute*
*3027 St. James*
*Belmont, CA 94002, USA*

Pascal Raevel
*Greet Ingenierie*
*8G, Rue Gen. de Gaulle*
*Merville F-5G660, France*

Michael Rager
*3D International*
*781 Neeb Road*
*Cincinatti, OH 45239, USA*

Bill Rayner
*Public Service Co. of North Carolina, Inc.*
*P.O. Box 698*
*Gastonia, NC 28054, USA*

Joe Reinemann
*Natural Resource Group, Inc.*
*100 N. Sixth Street #890 C*
*Minneapolis, MN 55403, USA*

Terry Rice
*City & County of San Francisco*
*P.O. Box 160*
*Moccasin, CA 95347, USA*

Paul Richarads
*Earth Tech*
*450 Bedford Street*
*Lexington, MA 02173, USA*

Mark Riforgiat
*Ecology and Environment, Inc.*
*368 Pleasantview Drive*
*Lancaster, NY 14086, USA*

Ben Rimes
*Entergy Services, Inc.*
*5755 Choctaw*
*Baton Rouge, LA, USA*

Joel Rinebold
*Connecticut Siting Council*
*10 Franklin Square*
*New Britain, CT 06091, USA*

Ted Ringger
*Baltimore Gas & Electric Co.*
*7609 Energy Parkway, Suite 101*
*Baltimore, MD 21226, USA*

Timothy Robbins
*The Wyatt Group, Inc.*
*P.O. Box 4423*
*Lancaster, PA 17604-4423, USA*

Jorge Roig-Soles
*Red Electrica*
*Po Del Conde de los Gaitanes, 177*
*8109 Alcobendas, Madrid, Spain*

Charles Rowell
*Louisiana Tech University*
*P.O. Box 10138*
*Ruston, LA 71226, USA*

Scott Rowland
*Chambers Group, Inc.*
*16700 Aston Street*
*Irvine, CA 92606, USA*

Art Roybal
*Western Area Power Administration*
*1627 Cole Blvd.*
*Golden, CO 80401, USA*

Robert Salzer
*Transco*
*P.O. Box 1396*
*Houston, TX 77251, USA*

Annie Marie Sanchez
*Public Service of New Mexico Envir. Services*
*MS 0408 Alvarado Square*
*Albuquerque, NM 87158, USA*

Michael Saunders
*Arizona Electric Power Cooperative*
*P.O. Box 670*
*Benson, AZ 85602, USA*

Chuck Scarborough
*Texas Utilities*
*1601 Bryan Street, STD.09-092*
*Dallas, TX 75201, USA*

Jon Schmidt
*Fugro Environmental Consultants*
*6 Maple Street*
*Northborough, MA 01532-1662, USA*

Karl Schoeberl
*Central Hudson Gas & Electric Corp.*
*284 South Avenue*
*Poughkeepsie, NY 12601, USA*

Bill Scott
*Ontario Hydro*
*700 University Avenue, 6th Floor*
*Toronto, Ontario, Canada M5G 1X6*

Ian Scott
*Canadian Association of Petroleum Producers*
*2100, 350 7th Avenue SW*
*Calgary, Alberta, Canada T2P 3NT*

Brent Sellers
*Newfoundland and Labrador Hydro*
*P.O. Box 12,400*
*St. John's, Newfoundland, Canada A1B 4J6*

Joseph Settles
*East Kentucky Power*
*976 Villa Drive #10*
*Richmond, KY 40475, USA*

Sandra Shaw Patty
*Maryland Dept. of Natural Resources*
*Tawes Street Off. Bldg. B-3*
*Annapolis, MD 21401, USA*

Phil Sheridan
*Meadowview Biological Research Station*
*8390 Fredricksburg Turnpike*
*Woodford, VA 22580, USA*

Linda Shumway
*GAI Consultants, Inc.*
*570 Beatty Road*
*Monroeville, PA 15146, USA*

Scott Shupe
*Niagara Mohawk Power Corp.*
*Envir. Affairs Dept., A-2, 300 Erie Blvd. W.*
*Syracuse, NY 13202, USA*

Daniel Simpson
*Phenix Environmental, Inc.*
*30 Broadway, Suite 207*
*Kingston, NY 12401, USA*

Richard Skarie
*Natural Resource Group, Inc.*
*3343 39th Avenue S.*
*Minneapolis, MN 55406, USA*

William V. Slade
*New York Power Authority*
*123 Main Street*
*White Plains, NY 10601, USA*

Craig Smith
*TRC Mariah & Associates*
*605 Skyline Drive*
*Laramie, WY 82070, USA*

Roderick Soper
*Phenix Environmental, Inc.*
*30 Broadway, Suite 207*
*Kingston, NY 12401, USA*

Steven Spears
*Indiana Gas Company, Inc.*
*8399 Zionville Road*
*Indianapolis, IN 46238, USA*

Christopher Standish
*Standish Brothers, Ltd.*
*35 Craig Street*
*Cookshire, Quebec, Canada J0B 1MC*

Thomas Stanton
*Algonquin Gas Transmission*
*1284 Soldiers Field Road*
*Boston, MA 02135, USA*

Wayne Staton
*Central Louisiana Electric*
*P.O. Box 5000*
*Pineville, LA 71361-5000, USA*

Chris Steeley
*SSI Mobley Company*
*509 SW Dykes Street*
*Cochran, GA 31014, USA*

Arvid Stendal
*Seattle City Light*
*700 Fifth Avenue, Suite 3100*
*Seattle, WA 98104-5031, USA*

Janet Stephenson
*Murphy Bros., Inc.*
*3150 5th Avenue*
*East Moline, IL 61244, USA*

Kathy Stephenson
*Bonneville Power Administration*
*P.O. Box 3621*
*Portland, OR 97208, USA*

Norman Stessing
*New York Power Authority*
*P.O. Box 277*
*Niagara Falls, NY 14302, USA*

Lowell Stivison
*Timberlands Enterprises Inc.*
*P.O. Box 557*
*Monticello, AR 71655, USA*

Pete Stone
*Alabama Electric Coop.*
*P.O. Box 550*
*Andalusia, AL 36420, USA*

Beverly Storey
*Texas Transportation Institute*
*707 Texas Avenue S. #E100*
*College Station, TX 77843-3135, USA*

Luis Fernando Suarez
*Interconexion*
*Calle 12 Sur, No 18-168*
*Medellin, Columbia*

Stan Sussman
*Electric Power Research Institute*
*3412 Hill View Avenue*
*Palo Alto, CA 94304-1395, USA*

Ben Swann
*Camp Dresser & McKee*
*1990 N. California Blvd., Suite 330*
*Walnut Creek, CA 94596, USA*

Mauricio Taam
*Furnas Centrais Eletricas Brazil*
*Rua Real Grandeza, 21G VL C*
*Rio de Janeiro, Brazil S1A 204*

David Thomas
*Georgia Power Co.*
*333 Piedmont Avenue, Bin #10190*
*Atlanta, GA 30308, USA*

Tyrone Thompson
*Atlantic Environmental Services*
*2232 Welsch IND OT*
*St. Louis, MO 63146, USA*

Gus Tillman
*The World Bank*
*1400 S. Joyce 719*
*Arlington, VA 22202, USA*

Steve Timmons
*Amicola Electric Membership Corp.*
*P.O. Box 10,*
*Jasper, GA 30143, USA*

Michael Tyrrell
*Earth Tech*
*450 Bedford Street*
*Lexington, MA 02173, USA*

Edward Uhlemann
*Natural Gas Pipeline Co. of America*
*701 E. 22nd Street*
*Lombard, IL 60148, USA*

Nelson Valderrama Banoy
*Interconexion Electrica S.A.*
*Calle 200, Correra 8, Santa Fede*
*Bogota, Columbia*

Rufin Van Bossuyt
*Consultant*
*125 Westboro Road*
*Upton, MA 01568-1033, USA*

Bill Vanderlyn
*Transco*
*2800 Post Oak Blvd.*
*Houston, TX 77056, USA*

Gene Vaughn
*Duke Power Company*
*13339 Hagers Ferry Rd.*
*Huntesville, NC 28115, USA*

Tammie Vincent
*Bonneville Power Administration*
*P.O. Box 3621*
*Portland, OR 97208, USA*

Jean Volkaert
*Cofiroute France*
*6–10 Rue Troyon*
*Sèvres Cedex, F-92316 France*

Mark Walmsley
*American Cyanamid*
*One Campus Drive*
*Parsippany, NJ 07540, USA*

Maria Webre
*Louisiana Dept. of Wildlife & Fisheries*
*P.O. Box 98000*
*Baton Rouge, LA 70898-9000, USA*

William Wells
*Arizona Electric Power Cooperative*
*P.O. Box 670*
*Benson, AZ 85602, USA*

Edward Wester
*Southern Ecosystems Research*
*6485 Lee Road 54*
*Auburn, AL 36830, USA*

George Wilder
*McCoy Tree Surgery*
*P.O. Box 817*
*Norman, OK 73070, USA*

Donald Wilkins
*Tennessee Valley Authority*
*186 South Quail Trail*
*Bowling Green, KY 42101, USA*

John Williams
*Alabama Power Company*
*600 North 18th Street*
*Birmingham, AL 35291, USA*

J. Randy Williams
*Entergy Services, Inc.*
*P.O. Box 61000*
*New Orleans, LA 70161, USA*

Lee Willingham
*Entergy Services, Inc.*
*5115 Thibault Road*
*Little Rock, AR 72204, USA*

Jan Wisniewski
*Wisniewski & Associates, Inc.*
*P.O. Box 1291*
*McLean, VA 22101, USA*

Joe Wisniewski
*Wisniewski & Associates, Inc.*
*P.O. Box 1291*
*McLean, VA 22101, USA*

Thomas Wojtalik
*Tennessee Valley Authority*
*1101 Market Street*
*Chattanooga, TN 37402-2801, USA*

Terry Wolverton
*Tuscarora Gas Trans. Co.*
*P.O. Box 30057*
*Reno, NV 89520, USA*

Don Woods
*Entergy Services, Inc.*
*P.O. Box 551*
*Little Rock, AR 72203, USA*

Terrence Yakich
*Wisconsin Electric Power*
*231 W. Michigan Street*
*Milwaukee, WI 53202, USA*

Robert Young
*Nova Scotia Power*
*P.O. Box 910*
*Halifax, Nova Scotia, Canada B3J 2W5*

Jerry Zak
*Atlantic Environmental Services*
*P.O. Box 297, 188 Norwich Ave.*
*Colchester, CT 06415, USA*

Kathleen Zuelsdorff
*Wisconsin Public Service Commission*
*610 Whitney Way*
*Madison, WI 53707, USA*

# Author index

# Keyword index